Sociocultural Explorations of Science Education 26

Alberto J. Rodriguez
Regina L. Suriel *Editors*

Equity in STEM Education Research

Advocating for Equitable Attention

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Sociocultural Explorations of Science Education

Volume 26

The series is unique in focusing on the publication of scholarly works that employ social and cultural perspectives as foundations for research and other scholarly activities in the three fields implied in its title: science education, education, and social studies of science.

The aim of the series is to promote transdisciplinary approaches to scholarship in science education that address important topics in the science education including the teaching and learning of science, social studies of science, public understanding of science, science/technology and human values, science and literacy, ecojustice and science, indigenous studies and science and the role of materiality in science and science education. Cultural Studies of Science Education, the book series explicitly aims at establishing such bridges and at building new communities at the interface of currently distinct discourses. In this way, the current almost exclusive focus on science education on school learning would be expanded becoming instead a focus on science education as a cultural, cross-age, cross-class, and cross-disciplinary phenomenon.

The book series is conceived as a parallel to the journal Cultural Studies of Science Education, opening up avenues for publishing works that do not fit into the limited amount of space and topics that can be covered within the same text. Book proposals for this series may be submitted to the Publishing Editor: Claudia Acuna E-mail: Claudia.Acuna@springer.com

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From Alberto J. Rodriguez
I would like to dedicate this volume to my precocious nephew and niece, Can and Maya, whose immense curiosity about the world fills me with joy and reminds me of how wonderful it is to be a science teacher. May all the teachers they encounter nurture their curiosity and learn with them.

From Regina L. Suriel
I dedicate this book to my two sons, Jason and Lucas. Thank you for your love and support. I also want to thank Alberto J. Rodriguez for his continuous leadership and mentorship.

Contents

Chapter 1
Contextualizing the Need for Supporting Social Justice-Driven Science/STEM Education Research

Alberto J. Rodriguez and Regina L. Suriel

In 2012, the National Research Council published the Conceptual Framework for the Next Generation Science Standards (NGSS) (NRC, 2012). This document ushered the overhaul of its 16 years old predecessor–the National Science Education Standards (NRC, 1996). What exactly happened then for almost two decades during the reign of the nation's very first national science education standards? How did these original standards impact teachers' practices, students' learning, the pervasive achievement gap between the have and have nots, and the engagement and participation of traditionally marginalized students in STEM-related careers? We actually do not know because no comprehensive impact study of the original science standards was ever conducted in order to inform the development of the NGSS (Rodriguez, 2015). Yet, since the crowning of the NGSS (Achieve, 2013), 20 states and the District of Columbia have pledged alliance to this new science education reform effort. However, just like ancient city states of Greece and hesitant to take any action that may be perceived as relinquishing power or independence, 24 other states remained unconvinced (and diplomatically) in the periphery. Quietly, nevertheless, and not to be outdone, some of these states revised their science curriculum to adopt very similar aspects of the NGSS, including its new 'shiny bell:' the integration of engineering practices (Rodriguez, 2015). Even though not all states have fully adopted the NGSS, or not adopted them at all, the NGSS has spurred the new craze for "everything STEM." So, now that almost another decade has passed since

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the NGSS was released, and now that in total we have had *25 years* of science reform efforts in the United States when we include both the original science education standards and NGSS, we must ask the same aforementioned question: *How did these standards impact teachers' practice, students' learning, the pervasive achievement gap between the have and have-nots, and the engagement and participation of traditionally marginalized students in STEM-related careers?*

If we start by recognizing how the rampant COVID-19 pandemic has revealed a great deal more how unprepared we are to face global health catastrophes, we will also notice the dangerous lack of scientific literacy from political leaders to members of the general public alike. This lack of scientific literacy has (and continues to) cost lives and much economic upheaval. How is this possible after 25 years and millions of dollars in support for these science reform initiatives? Starting with the year that the NGSS was published, 2013, according to the National Science Foundation's Directorate of Education and Human Resources (EHR) (n.d.), $833.31 million dollars were allocated for supporting educational research (NSF, 2013). The EHR is formed by four divisions: Division of Research on Learning in Formal and Informal Settings; Division of Graduate Education; Division of Human Resource Development; and the Division of Undergraduate Education. Therefore, these four divisions are responsible for supporting all forms of educational research in and out of school settings, as well as higher and adult education. According to EHR mission statement, they "support excellence in U.S. STEM education at all levels, in all settings for the development of a diverse and well-prepared workforce of scientists, technicians, engineers, mathematicians and educators and a well-informed citizenry" (EHR Introduction, para 2). Federal funding for educational research has remained steady since 2013, and in 2020 the EHR's allocation was $940 million (NSF, 2020). So, why are so many individuals from politicians with post-secondary degrees to regular working-class folks so determined to reject science, refusing to wear masks to protect themselves and their families, and even refusing to take a free and available lifesaving COVID-19 vaccine? Where is the "well-informed citizenry" EHR was charged to promote through educational research?

What about other federal funding agencies? What level of support are they providing for these STEM reform and scientific literacy efforts? Li et al. (2020) conducted a review of funding by the United States (US) Department of Education Institute of Education Sciences (IES). These authors found that from 2003 to 2019, out of the 127 projects funded with a focus on STEM-related topics, the majority (60.6%) of the projects received funding between 1 to 2 million. Projects receiving 3 or more million represented 16.5% of all funded studies during the same period.

Thus, while some may argue that more research funding is needed, there is no doubt that the science education community in the US has benefited from the available level of funding, and it has been actively producing publications that impact reform efforts here and in other countries. However, *how have this funding, reform efforts, and research productivity impacted teachers' practice, students' learning, the pervasive achievement gap between the have and have-nots, and the engagement and participation of traditionally marginalized students in STEM-related careers?*

The answer to this layered question unfortunately is not good, and the reasons given for why there is little to no sustainable improvements are the same as those we have been now hearing for decades. Just like a popular and enchanting sad song, all these reform efforts' melody may slightly change throughout the years by offering new catch phrases (e.g., *Science for All Americans, No Child Left Behind, less is more, everyone succeeds, engineering practices*, etc.) but the song's lyrics always ended up conveying the same message—and producing the same results. For example, highlights from the latest Elementary and Secondary STEM Education report (Center for Science and Engineering Statistics [CSES], 2021) are shared by Dr. Julia Phillips in a recent interview (Gillespie, 2021). Dr. Phillips is the Chair of the National Science Board's Committee on National Science and Engineering Policy. This is the committee in charge of supervising the production of science and engineering indicator reports in collaboration with the CSES. In the interview, Dr. Phillips starts with what it is now the canonical 'must stay competitive' argument (Rodriguez & Morrison, 2019). She states, "What we see [in the aforementioned report] is that the performance of children in the U.S. has not kept pace with the performance of students from other countries in science and mathematics for a decade or more" (Gillespie, 2021, para 4). These statements are almost identical lyrics to the same melody sung in the *Nation at Risk* report (NCEE, 1983), the first version of the National Research Council science standards (1996), and in the (Achieve, 2013). In terms of differences in student achievement, Dr. Phillips continues:

> You see huge differences in performance based on race and ethnicity, so that Asian and White students do much better on these standardized tests than students of color. And you also see that there is a huge difference based on the socioeconomic background of students – students that are from higher socioeconomic backgrounds do much better than students from low socioeconomic backgrounds (Gillespie, 2021, para 6).

Dr. Phillip then goes on to echo the traditional economic argument, "careers in science and engineering are some of the best careers that a young person can pursue in terms of opportunities for making a really good living" (Gillespie, 2021, para 9). Finally, we of course also hear the argument that has been sung in every reform report produced since the race for space was ignited by Sputnik in 1957: "...science and engineering are increasingly important for driving the US economy... If the U.S. is going to continue to have the wealth and prosperity that it has come to enjoy, being in the lead in many of these industries is going to be very important" (para 10).

While all of Dr. Phillips' arguments do matter, and while we continue to learn a great deal from educational research, it is obvious that we need to reflect upon and refocus science education reform efforts so that more sociotransformative outcomes are evident. That is, outcomes that significantly (and sustainably) impact teachers' practices and students' engagement and successful participation in STEM-related fields (Rodriguez & Morrison, 2019). We do not claim to have all the answers, neither do we intend to offer a 'shinier bell' to chase after. Rather, in this edited volume, we propose that in order to interrupt this on-going cycle of truncated (and costly) education reform efforts, funding agencies and researchers should make equity, diversity and social justice in science/STEM more central in all their endeavors. This implies that equity, diversity and social justice should not be used like commodity constructs that could ensure funding by having them superficially sprinkled on research proposals. Instead, we argue that funding agencies should promote and hold researchers accountable for the integration of equity and diversity *throughout* their proposal submissions and implementation. Similarly, researchers should be held accountable for the intellectually honest evaluation of their projects' impact on the very people's lives upon which they build their research (Tolbert et al., 2018).

In this edited volume, the contributors provide examples of important equity science/STEM research being conducted against the odds. That is, studies conducted with limited funding ($50,000 or less) in a variety of educational contexts, including urban, rural, formal, informal, and international. We argue that this is the kind of equity-centered research that should be targeted for more funding and should be receiving fairer attention by journal editors/reviewers if we are interested in learning and breaking away from the constant cycle of predominantly barren science education reform efforts.

The contributors of this volume also cover all educational levels, i.e., elementary, middle, and high schools, pre-service teachers and engineering undergraduate programs, and teacher professional development. In terms of previous work experience, our contributors have worked as schoolteachers, engineers or scientists, sometimes also teaching in bilingual contexts, as several of the authors are also English language learners.

With equivalent representation from the traditional sex binary of male or female, most of the contributors are scholars of color, including individuals who identify themselves as Latinos/as, African (Black), Asian, Indian (South Asia), and White. Regrettably, we were unable to secure contributions from First Nations' colleagues as the current pandemic significantly affected this ethnic group the most. We also wish we had the voices of colleagues who identify with non-binary sex/gender categories, as well as the voices of colleagues who mainly conduct research with participants with special needs in science/STEM education. We hope, however, they may feel encouraged by this publication to compile a similar volume to also draw attention to their important work.

Using a variety of qualitative research methods (such as counterstories, case studies, and autoethnography), this volume includes ten chapters with the first three after the introduction focusing on K-12 students. Chapters 5, 6, and 7 focus on pre- or in-service teacher professional development, and Chaps. 8 and 9 address higher education faculty and their efforts to address equity, diversity, and social justice in their working contexts. Chapter 10 provides an afterword reflective of the work included in this book. Below, we provide a brief synopsis of each chapter.

Chapter 2. Communicating with Objects: Supporting Translanguaging Practices of Emergent Bilingual Students During Scientific Modeling by Enrique H. Suarez

In this chapter, Dr. Suarez challenges English-centric approaches for assisting and assessing students' investigative inquiries of scientific phenomena. He eloquently defines the process of translanguaging and sheds light on the complex ways emergent bilingual students (EBS) communicate, especially when learning science. His study, conducted in a limited-funding science-based out-of-school program, demonstrates how a fourth grade EBS used science artifacts to explain electrical resistance while translanguaging. Dr. Suarez then provides insights into curricular design considerations for including science artifacts that can support EBS with investigating and communicating their insights about the natural phenomena they observe. As the number of emergent bilinguals in science classrooms continues to increase, we know that the need for more socially just and asset-based instruction that draws on EBS linguistic competencies is pressing. Therefore, Dr. Suarez calls for funding considerations that could (and should) support and promote graduate research in science education targeting social justice agendas.

Chapter 3. Fostering Social Connectedness and Interest in Science Through the Use of a Sports Model by Sheron Mark, Matthew Trzaskus, Lauren Archer, and Peter Azmani
Dr. Sheron Mark et al. draw our attention to the benefits for developing social connectedness with our students. They argue that social connectedness can help support positive learning environments and can lead to students' self-driven motivation to participate in learning. The authors' high school biology activity designed to increase social connectedness between urban teachers and their students was successful in this regard and highlight unique opportunities for teaching and learning though organized sports and for increasing students' engagement with biology concepts. The authors also stress that journal editors and reviewers tend to neglect these kinds of studies because of their preference on quantitative over qualitative methods. However, they challenge editors and reviewers to pay more attention. Projects with a socially-just and culturally relevant emphasis could help us better understand how instructional practices can become more effective when teachers and students share professional and mentoring relationships leading to increased motivation for learning and cognitive development.

Chapter 4. Science Teachers' Views on the Integration of Science and Language for Emergent Bilinguals in Sixth-Grade Classrooms by Sissy Wong, Jie Zhang, Araceli Enriquez-Andrade, and Ma. Glenda Lopez Wui
In this chapter, Dr. Wong et al., illustrate how challenging it can sometimes be to help teachers move away from strongly held, low academic and performance expectations of emergent bilingual students (EBS). Using a qualitative approach, the authors document their efforts to assist teachers in implementing a unit that promoted the integration of science and language literacy through the discussion of a controversial socioscientific issue. While the teachers conceptually embraced the goals of the intervention, their low academic and performance expectations for EBS, compounded by the school's institutionalized oppressive practices, such as pacing guides and English only policy, prevented them from meeting the needs of all their students. The authors argue for the need to provide funding that would allow for the kind of comprehensive and longitudinal form of teacher professional development necessary to effectively address deeply held ideologies of low expectations.

Chapter 5. Teacher Candidates and the Equitable, Inclusive Science Classroom by Joi D. Merritt and Angela W. Webb

Teacher Preparatory Programs (TTP) are charged with developing teachers' knowledge and skills for teaching all students, especially the growing number of students who are culturally and linguistically diverse (CLD). Teacher educators face various challenges with preparing teachers to teach CLD students. These challenges often include opposition to culturally relevant practices that range from various sociopolitical orientations to very personal and professional beliefs. These orientations and beliefs are often manifested in the actions and practices of leaders of TTPs and schools, teacher educators, mentor teachers and preservice teachers. Against the backdrop of ideological resistance toward equity and inclusion, in this chapter, Drs. Merritt and Webb share their experiences with revamping the elementary and secondary science methods courses in preparing teacher candidates to teach CLD students. They share the outcomes of the strategies they implemented in their courses, as well as personal insights on the ways in which their engagement in this study have affected their teaching, research and service. The authors also share their struggle with attracting funding opportunities and with publishing this kind of transformative work.

Chapter 6. Exposing Inequities Within Teacher Professional Development and Its Impact on Advancing Equity, Diversity and Social Justice in STEM Education by Regina L. Suriel and Kristy Litster

With an increasing student population of culturally and linguistically diverse (CLD) learners, it is important that science teachers are effectively prepared to meet the learning needs of all students, especially CLDs. Drs. Suriel and Litster provide a strong rationale for the need to support teachers' professional development in culturally relevant pedagogy. The authors then shift our gaze to a discussion of teacher development programs, most of which are not adequately preparing science teachers to teach CLD learners. As an example, the authors shed light on a well-funded science professional development program that ran for 14 straight summers in a region with high CLD and low-SES students. This program was held to little or no accountability measures for developing teachers' understanding of equity and diversity in science teaching, even though it was funded on the promise of providing teacher professional support in these areas. This means that participating teachers did not have significant opportunities to engage in culturally relevant practices, nor were they held accountable for demonstrating growth in culturally relevant teaching (CRT) designed to assist their CLDs. As an alternative, the authors showcase a STEM-based program and other learning activities that are available at low- or no cost to assist in developing strong STEM teachers who can work effectively with CLDs. The authors conclude by arguing for adequate funding of STEM-based professional development that clearly requires (and upholds) accountability measures for CRT and curricula if we are to increase the number of culturally and linguistically diverse students in STEM.

Chapter 7. Exposing the Invisibility of Marginalized Groups in Costa Rica and Promoting Pre-service Science Teachers' Critical Positional Praxis by Alberto J. Rodriguez and Marianela Navarro-Camacho

This chapter is based on findings from a mixed-methods longitudinal project Drs. Rodriguez and Navarro-Camacho carried out with secondary pre-service science teachers in Costa Rica. Informed by sociotransformative constructivism (sTc), the authors sought to promote the cross-cultural and transdisciplinary STEM professional preparation of pre-service teachers during the last year and half of their program. The project is on-going and preliminary data showed significant gains in the participants' perceptions of preparedness to integrate cross-cultural and transdisciplinary STEM in their practice. However, this chapter mainly focuses on teacher identity development as this construct became a surprisingly interesting point of dissonance among researchers and participant students. In short, the chapter documents how through an autoethnographical exploration the authors and students engaged in (re)constructing taken-for-granted notions of ethnic/cultural identity. Furthermore, the authors argue that having a well-grounded sense of identity could help us advance equity and social justice issues in the science classroom. This chapter provides a compelling example for the need to promote and support more international collaborations with developing countries. Currently, except for the Fulbright Scholar Program (which supported the first author), there is very little funding support provided by funding agencies and universities.

Chapter 8. The Journey of Decolonization as a Scientist and Science Education Researcher by Rasheda Likely and Christopher Wright

Historically, the science curriculum has presented traditional scientific views and has continued to reflect the practices, beliefs, and dispositions of scientists and engineers, as mandated by the leadership in science education. Similarly, the science curriculum in public schools often reflects the voices of those in power, primarily of the White male scientists whose ideas have dominated science textbooks throughout time. Black girls in middle schools may not relate to privileged White male scientists they only read about, thus, for Dr. Rasheda Likely, the need to decolonize the science curriculum became important. As a Black female scientist and science educator, Dr. Likely shares her professional journey with designing a decolonized science curriculum for an afterschool enrichment opportunity targeting Black middle school girls. Using a critical autoethnographic methodology, the authors present study findings on the implementation of the asset-based science curriculum on Black hair and skin care. Most importantly, the authors argue that the researcher's process of decolonizing her own assumptions and expectations of what counts as science education research through a grief cycle was an essential practice for partaking in research with girls from historically excluded communities from science. The authors argue that explicit and intentional disruption by subtle hierarchies within science education has previously prevented this and similar self-decolonizing reflections from being published. They call on researchers, curriculum developers, journal editors, and other publishers to be introspective and apply these critical frameworks in their practice and review process.

Chapter 9. Striving for More: Beyond the Guise of Objectivity and Equality in Engineering Education by Randy Yerrick, Michael G. Eastman, Monica L. Miles, Ramar Henderson, and Ram Nunna

Why do engineering institutions experience a juxtaposition between resources put into diversity programs and efforts that stifle the results of these initiatives? For every engineering school that puts considerable energy into diversity initiatives, we observe the same school reaping very few of the benefits thereof. Inadvertently or not, from administration to faculty there are attitudes, policies, and practices that harm these efforts and curtail the flourishing of diverse students and faculty, and the development of a new forward-thinking culture. This chapter explores these often poorly understood factors and demonstrates them through three real life vignettes highlighting the experiences of diverse faculty and students. Finally, possible solutions are offered, and the guidelines for new ways of thinking about diversity in engineering education are laid down.

Chapter 10. "What Have You Done For Me Lately": An Afterword by Terrell R. Morton

In this afterword, Dr. Morton draws attention to the core and common arguments across all the chapters of this volume and calls upon everyone (funding agencies, policy makers, journal editors and reviewers, and education researchers in general) to open their eyes and seek to more purposely use their positions of privilege to effect transformative change.

In short, the collection of chapters in this edited volume aims to shine a light on the creative and transformative work of scholars who are advancing social justice through science/STEM education with limited resources ($50,000 or less). Our goal is by no means to reify the misguided and neoliberal notion of "doing more with less" for those whose needs are greatest. On the contrary, we seek to draw attention to the significant body of work being conducted in various contexts so that readers could reflect and appreciate how much broader and transformative our impact could be if funding agencies, policy makers, and other researchers would widen their perspective and seek to promote similar equity and diversity-centered scholarship (Fortney et al., 2019). After all, and as explained earlier, continuing to support (and publish) traditional research for the last 25 years based on the two reincarnations of the science education standards have not produced the kind of transformative results our ever increasingly diverse student population deserves. Similarly, the research articles being published with a focus on equity, diversity and/or social justice continue to be a small fraction compared to mainstream research articles. For example, in a recent chapter, Espinet et al. (2021) explain that from 2011 to 2018, the *total* percentage of articles addressing equity issues in top science education journals, such as the *Journal for Research in Science Teaching*, *Science Education,* and *Research in Science Education*, were 17%, 11.7% and 5.9%, respectively. When the authors performed the same review using this time the construct *linguistic diversity*, the *total* percentage of articles addressing this topic in the same journals plummeted to 3.6%, 3.2% and 2.5% respectively.

We sincerely hope that this volume—this letter in 10 chapters to funding agencies, research journal editors, reviewers, researchers, and policy makers–will generate discussion and reflection on the importance of centering equity, diversity and social justice in science education reform and research. In fact, we need a dimension of equity, engagement diversity and social justice to more responsively (and responsibly) guide research funding, teacher development and supportive accountability efforts (Rodriguez, 2015).

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Regina L. Suriel is an associate professor of Science Education in the Department of Teacher Education at Valdosta State University. As a previous bilingual high school science teacher in NYC multicultural schools, her research centers on increasing the participation of Culturally and Linguistically Diverse (CLD) students in science through effective and socially just curricula. Her work addresses the integration of culturally responsive pedagogy and scientific models. She also supports effective mentorships of Latinx faculty in Institutions of Higher Education and has published works in this area. Regina is a founding member and past program chair for Science Educators for Equity, Diversity and Social Justice (SEEDS), a science education research organization dedicated to advancing social justice through science/STEM education. She was past Chair of the Elections Committee and serves as Chair for the Latinx Research Interest Group at the National Association for Research Science Teaching. She is also an Editorial Board member for the Journal of Science Teacher Education among other editorial boards.

Chapter 2
Communicating with Objects: Supporting Translanguaging Practices of Emergent Bilingual Students During Scientific Modeling

Enrique Suárez

2.1 Introduction

We are at a pivotal moment for PK-5 science education, as the field continues to embrace the "practice turn" (Manz, 2015), full of promises and tensions on how to improve the quality of science teaching and learning for minoritized students (Morales-Doyle et al., 2019). These efforts focus on creating opportunities for students to learn science through engaging in scientific practices, such as discussing evidence-based explanatory models. Yet, as the number of students of who speak English as an additional language grows across the United States (OELA, 2020), the policies, practices, and research agendas that inform science education often do not hold these students' best interests at heart. For one, there has been a sustained and misguided emphasis on centering instruction on acquiring English as a pre-/co-requisite for investigating the "hows and whys" of natural phenomena. Under the assumption that "you can't do the learning if you don't have the language" (quote from a PK-5 teacher on the perceived need to front-load vocabulary), these approaches to research and instruction are rooted in a language ideology – beliefs or feelings about languages and how people use them (Kroskrity, 2004) – that creates a linguistic power hierarchy, with written and spoken academic English at the top. Relatedly, in this chapter I refer to these students as Emergent Bilingual Students (EBS), building on the work of critical scholars who reject deficit-based acronyms (e.g., ELLs) and celebrate students' bilingualism, biculturalism, and highlight that they learn more than English (González-Howard & Suárez, 2021; Gutiérrez & Orellana, 2006).

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English-centric instruction is often represented in the vocabulary lists in textbooks and the word-walls that line PK-5 classrooms, filled with words that EBS are supposed to memorize and use when describing their insights about natural phenomena. This stance has been supported by research agendas that frame emergent bilingual students' ways of communicating as insufficient for learning science, and use these students' language practices as steppingstones for developing ostensibly more sophisticated discourses (e.g., Kang et al., 2017). The emphasis on white English-centric instruction that privileges the acquisition of vocabulary has also extended to the use of *realia* (Short, 1991): pairing words with the objects and/or pictures to support EBS memorize academic language, such as science vocabulary (Kinard & Gainer, 2015).

While seemingly sensible, privileging the acquisition and use of academic English effectively narrows the scope of "what counts" as productive communication in the learning environment, creating a linguistically unjust learning environment (Flores, 2020). For one, this approach reduces the possible communication strategies that EBS can rely on to co-construct knowledge, explicitly or implicitly messaging to students that their languaging practices are not sophisticated enough for learning science. Moreover, researchers and educators who focus on the memorization and repetition of English-based academic language run the risk of overlooking, misrecognizing, and undervaluing the wide range of creative ways that EBS can develop and use to share their observations and ideas of natural phenomena. These researchers and educators are also in danger of acting as "white listening subjects" (Flores & Rosa, 2015), assuming that by acquiring respectable ways of communicating, such as scientific vocabulary, students' ideas will become more valuable, without recognizing it is the system built on linguistic injustices that denigrate students, their ideas, and their ways of communicating. Finally, research and pedagogical agendas that privilege dominant forms of English-centric communication oversimplify, or even ignore, the important role that material artifacts can have on mediating multilingual, multimodal, and multisensory action and communication between multilingual speakers. In this chapter, I challenge these linguistic injustices by broadening definitions of what counts as productive forms of communication that elementary-aged EBS leverage when investigating natural phenomena, focusing on the role that science artifacts play in supporting the students to communicate their observations and ideas.

To push back against these linguistic power hierarchies and deficit frames of how EBS learn science, I draw on the theory of *Translanguaging* to argue that justice-oriented science education must identify, value, and leverage students' complex communicative practices when investigating natural phenomena (Poza, 2016; Suárez, 2020). Specifically, translanguaging is defined as "the deployment of a speaker's full linguistic repertoire without regard for watchful adherence to the socially and politically defined boundaries of named (and usually national and state) languages" (Otheguy et al., 2015). Translanguaging offers a theoretical and pedagogical lens for understanding how EBS leverage their full *semiotic repertoires* (Kusters et al., 2017), a collection of linguistic and non-linguistic resources that learners marshal when communicating to make meaning of the world. From this perspective, I take communication to be a multilingual, multimodal, and multisensory process (Li, 2018) that is much broader than the written and spoken English-based forms of communication that have become expected, practiced, and enforced in PK-5 classrooms. More recent work focuses on the role that material environments play in supporting communication and meaning-making between multilingual speakers (Zhu et al., 2017a, b), but primarily in non-educational spaces (e.g., shops).

In this chapter, I build on research in science education, social semiotics, and critical sociolinguistics to address the following question: how does a young EBS laminate speech, gestures, and science artifacts as part of her translanguaging practices when sharing her explanatory models about electrical phenomena? I analyze data from an out-of-school program for elementary-aged EBS that I intentionally designed to promote students' languaging practices in the service of investigating electrical phenomena, such as circuits and electrical resistance. Through my analyses, I shed light on the complex ways EBS communicate, especially when learning science, as well as provide insights into design considerations for including science artifacts that can support EBS with investigating and communicating their insights about the natural phenomena they observe. Moreover, I emphasize the need for intentional funding opportunities and structures that reflect our commitments towards equitable science education.

2.2 Theoretical Framework

2.2.1 A Vision for Equitable Science Education for Emergent Bilingual Students

The recent shift in science education is supported by research that argues that students should explore the "hows and whys" that undergird natural phenomena through engaging in science practices, such as how to engage in productive discussions about evidence-based claims (Berland et al., 2016; Manz, 2015). The emphasis on learning through engaging in practices is supported by sociocultural and cultural-historical theories that frame learning as the development of diverse repertoires of cultural practices created and valued by learning communities (Nasir et al., 2014). From this perspective, justice-oriented science learning environments should build on students' diverse meaning-making repertoires, pushing back against the "rather narrow range (or repertoire) of ways of speaking, knowing, acting, and valuing that are privileged" in most science learning environments (Bang et al., 2017, p. 34). Thus, the goal is to design equitable science learning opportunities that are heterogeneous in nature (Rosebery et al., 2010), coordinating science practices with students' ideas and ways of talking, rather than replacing one with the other.

However, there are prevalent and prominent research agendas that limit the kinds of repertoires that EBS should leverage in science learning environments (Jung & Brown, 2016; Kang et al., 2017). Specifically, these agendas frame EBS' experiences and ways of communicating as insufficient for investigating natural phenomena; students' own semiotic resources are only seen as valuable as long as they can help EBS to develop English-based science discourses and vocabulary. I argue that these white English-centric, deficit frames of EBS are in direct contradiction with a justice-oriented approach that privileges heterogeneity and, therefore, contribute to and reify linguistic power hierarchies that marginalize EBS in science learning environments. Thus, I propose that justice-oriented science education must identify, value, and leverage students' languaging practices when making sense of natural phenomena (Suárez, 2020).

2.2.2 Investigating and Communicating About the Natural World Through Science Artifacts

An effective strategy for supporting children explore the "hows and whys" of phenomena is to create opportunities for them to investigate natural phenomena through interacting with tangible science artifacts. This has been the main goal of constructionism (Papert & Harel 1991), focusing on how the design of tangible artifacts can support learners identify, analyze, and interpret salient features and patterns of natural phenomena and interesting problems. Through these interactions, learners can pose questions about the natural world, make sense of phenomena and/or relevant problems, and represent their understanding through a final artifact. To support these kinds of meaning-making, designers of material resources and learning environments must carefully consider the makeup of tools and their use in relation to the environments' learning and participation goals (Peppler & Danish, 2013). However, only making science artifacts available to students from non-dominant communities is not sufficient for disrupting preconceived notions of how these students co-construct knowledge about the natural world (Vossoughi et al., 2016). Moreover, most of this research has been informed by monoglossic language ideologies, which is why we must ask how science artifacts can create opportunities for EBS to develop and engage in science practices to investigate natural phenomena.

Scholars within the fields of pragmatics, applied linguistics, and social semiotics have studied the role that physical objects play in supporting action and communication. Chuck Goodwin's scholarship is particularly helpful for understanding the complex communication strategies that children develop and/or use in the service of sense-making, specifically his "analysis of action within human interaction that takes into account the simultaneous use of multiple semiotic resources by participants" (Goodwin, 2000). Goodwin argues that communication and action are complex and contextual processes where interlocutors efficiently decide which semiotic resources are relevant and timely to aid in collaborative meaning-making (Goodwin, 2000). Specifically, Goodwin frames communication and action as processes where interlocutors are simultaneously bringing into coordination a wide range of semiotic fields that are then organized as substrates (i.e., laminated) upon which people can co-construct meaning (Goodwin, 2013). Moreover, Goodwin argues that material structures (e.g., inscriptions, artifacts) can act as semiotic foundations upon which multimodal and multisensory forms could be coordinated and disambiguated. Therefore, communicative environments that include material structures, such as tangible science artifacts, could offer opportunities for children to co-construct science knowledge through laminating various semiotic resources and objects.

While productive for imagining the role that tangible objects can play in supporting communication and sense-making, Papert's constructionism and Goodwin's lamination of semiotic fields do not explicitly account for the linguistic power hierarchies that are present and enforced in most learning environments, such as PK-5 science learning environments. Despite arguing for and describing how engaging with objects benefit learners, these theories do not explicitly attend to how (unjust) language ideologies can curtail the sense-making opportunities afforded by the material field. To address this limitation, I draw on translanguaging to disrupt the socially-constructed power hierarchies that constrain how EBS communicate.

2.2.3 Translanguaging: Disrupting the Power Hierarchies that Separate Semiotic Resources

Translanguaging is a critical theoretical framework that breaks down the boundaries between spatial, linguistic, and non-linguistic semiotic resources, generating new configurations of language practices, understandings, and social structures (Zhu et al., 2017a, b). Considering speakers' languaging practices rest on the multilingual, multimodal, and multisensory nature of communication (Li, 2018), applied linguists and social semioticians have recently begun to inquire into how multilingual speakers recruit and rely on the material structures within their surroundings for collaborative meaning-making (Zhu et al., 2017b). While initial definitions of translanguaging focused on written and spoken modalities of language (Otheguy et al., 2015), more recent efforts have purposefully focused on the multiple semiotic resources that speakers develop and use in organizing sociocultural spaces. Specifically, Zhu and her collaborators argue that multilingual speakers "draw on various multilingual, multimodal, and multisensory resources available as they engage in everyday activities, in ways that draw attention to linguistic relations, artifacts, spatial organization, gender, ethnicity, and other multimodal, sensory, and spatiotemporal properties" (Zhu et al., 2017b, p. 385). Thus, attending to the linguistic, non-linguistic, and spatial semiotic resources that children develop and leverage in their language practices is a consequential step towards transformative learning environments, interrogating and disrupting socially constructed linguistic power hierarchies.

2.3 Methods

In this chapter, I present the findings from a study that focused on answering the following research question: how does a young EBS laminate speech, gestures, and science artifacts as part of her translanguaging practices when sharing her explanatory models about electrical phenomena? This study is part of a broader project focused on investigating how young students understand the transmission and transformation of electrical energy. Despite its role in the K-5 science standards (e.g., NGSS: 4-PS3), there is limited research on how young students understand electrical resistance (Suárez, 2020). Elementary school science curricula have tended to teach about electrical resistance in the form of a binary (i.e., conductors and insulators), which obscures how electrical energy is transmitted and/or transformed through electrical resistors. Framing and investigating the flow of electricity and electrical resistance on a spectrum, however, can support elementary-aged students in developing a more robust conceptual understanding of energy, particularly through the co-construction of explanatory models that address the hows and whys behind the transmission and/or transformation of electrical energy in an electrical circuit.

2.3.1 Designing a Learning Environment to Investigate Electricity

To understand the complexity of the learning environment and how students investigated electrical phenomena, I leveraged a Design-Based Research (DBR) approach (Cobb et al., 2003). Specifically, this methodology allowed me to explicitly state and operationalize my design conjectures (i.e., estimations of how the implementation of the design should go) and theoretical conjectures (i.e., inferences about how the implementation of the design supports the intended learning outcomes) about how science artifacts could support EBS to investigate and communicate their insights about electrical phenomena (Sandoval, 2014). An iterative DBR approach was advantageous for formulating and refining localized theories about how students in the program learned about electrical phenomena and the means to support their learning.

Building on my theoretical framework, I generated two main high-level conjectures that described how tangible experimental tools could support EBS to investigate and communicate their insights about the transmission and transformation of electrical energy. Drawing on constructionism, the first high-level conjecture proposed: *tangible experimental tools need to make visible salient features of electrical resistance for students to identify and investigate*. I operationalized this conjecture by intentionally including science artifacts that would reveal to students how the transmission and transformation of electrical energy is dependent on the properties of resistors. Specifically, I designed investigations around different kinds of circuitry materials that made different aspects of electrical resistance visible to students, such as traditional materials used for building circuits (e.g., batteries, bulbs, wires) and CircuitScribe™ gel pens with conductive ink, which functioned similarly to wires (Russo et al., 2011). The latter were particularly transparent because students could draw the "wires" of the circuit allowing them to, essentially, construct their own resistors; they choose the geometry of the lines they drew when completing a circuit and, therefore, changing the lines' electrical resistance. For instance, increasing or reducing the length of a line of conductive ink changes its electrical resistance. All of these materials provided students with immediate feedback on the effects of changing properties of circuits and resistors, as well as changing the flow of electricity in order to problematize it.

The second high-level conjecture drew on the critical framework of translanguaging and stated: *having access to tangible science artifacts can support EBS to leverage multilingual, multimodal, and multisensory resources when sharing their ideas and reasoning about electrical phenomena*. This conjecture was meant to expand the narrow forms of communication privileged in science learning environments, especially those have been standardized as objective and used to stigmatize racialized people's linguistic practices (i.e., appropriateness-based; Flores & Rosa, 2015), and push back against prioritizing academic language. I operationalized this conjecture through designing an environment that included and promoted multiple material means for students to share and engage with others' observations, ideas, and reasoning. I also tried to embody this conjecture through enacting a critical pedagogy that invited, valued, and built upon how the students laminated speech, gesture, investigation materials, writing, and/or drawings (i.e., semiotic bundle; Pennycook, 2017). Rather than subtly replacing or correcting students' strategies for communicating about phenomena, I leveraged the various multilingual, multimodal, and multisensory semiotic resources students developed and used. My goal was to legitimize students' communication strategies, especially those that centered around the science artifacts.

2.3.2 Context, Participants, and Curriculum

This study took place in an out-of-school science program I designed and implemented in partnership with my neighborhood's local library system and enrolled elementary-aged emergent bilingual learners. Library administrators were excited and supportive of creating a science-based program for their younger patrons, especially one that would run for a sustained period of time and would serve emergent bilingual students. The program was offered three times throughout the calendar year (Spring, Summer, Fall), completely free of cost, at different library branches that served predominantly immigrant families. In this chapter I analyze data from the Summer implementation in the Dexter library (pseudonym), a branch that served a neighborhood of predominantly African-American and immigrant families from Central America, Sub-Saharan Africa, and East Asia. In this iteration, the program enrolled approximately 15 students, but only four consented to participate in the study. Enrolled students spanned all elementary school grades, with the majority of students being in or having completed third and fourth grade. All the students who consented to being part of the research were emergent bilingual and represented a wide range of home languages. Given that the program was offered within public libraries, I did not turn away students who were monolingual English speakers; however, none participated in the research at Dexter. English became the program's lingua franca, although students were encouraged to speak to each other using whichever named languages they found useful.

The program was structured in eight (8) sessions in which students engaged with different activities for investigating electrical phenomena; each session lasted approximately sixty (60) minutes. Each session was guided by a driving question related to electrical phenomena, which students attempted to answer through investigations and discussions. Activities were sequenced in order to gradually introduce students to different electrical phenomena, acting as a progression of sorts that went from the flow of electricity to how to regulate that flow. Overall, the program was divided into three major tasks, each of which had specific science artifacts associated with them: investigating traditional circuit phenomena (Sessions 1–4), testing conductors and insulators (Sessions 6–7), and exploring the geometry of lines of conductive ink (Session 5, 7–8).

2.3.3 Data Collection and Retrospective Analyses

For this study, I collected data from two main streams: video and audio recordings of classroom interactions, and student-produced artifacts. I prioritized video data because it could yield the most information on how participating students interacted with the tangible experimental tools when investigating and discussing the electrical phenomena they observed. The cameras were positioned to capture students' ideas, gesturing, and interactions with the science artifacts, especially when engaging with other students. Finally, I collected still images of work students produced during the investigations, prioritizing the inscriptions students produced for sharing their explanations, as well as the experimental setups they designed for collecting data to address the sessions' driving questions (e.g., paper with drawn circuits of differing lengths/widths). Given the conceptual and semiotic complexity of the learning environment, collecting data from a wide range of sources allowed me to triangulate and corroborate the converging conclusions of my analyses and, therefore, increase the trustworthiness and validity of my claims (Miles et al., 2013). All data collection procedures were approved by my university's Internal Review Board (IRB).

My approach to analyzing the collected data was qualitative in nature. The first step in the retrospective analysis was to strategically condense the data into manageable and accessible pieces (Miles et al., 2013) that could be revisited for finer-grained analysis. Specifically, I created multimodal content logs that summarized the video and audio recordings by dividing these data into 5-minute segments, describing students' participation and communication in the investigation, as well as the artifacts involved in their investigations and explanations. These logs also included analytical notes that focused on students' observations and explanations about electrical phenomena, how the science artifacts made properties of electrical resistance visible to students, and the different modalities students leveraged when communicating their ideas (e.g., speech, drawings, gestures). For this chapter, I selected episodes from the logs that included a translanguaging event situated within a semiotic bundle (Pennycook, 2017): an analytical unit situated in local learning activities where participants (e.g., learners, instructors) leverage linguistic resources associated with two or more named languages (e.g., English, Spanish), and/or non-linguistic resources (e.g., gesturing), all in coordination with science artifacts or inscriptions in the service of collaborative meaning-making. Specifically, I present three episodes of how Yesenia, a Mexican-origin fourth grader, investigated and communicated her insights about electrical phenomena through bringing together and organizing speech, gestures, and objects (i.e., semiotic lamination).

To understand how tangible science artifacts made visible properties of electrical resistance, I inductively created first-cycle codes (Miles et al., 2013) that captured the properties of electrical resistance students alluded to when investigating electrical phenomena. This set of first-cycle codes were then organized into more general second-cycle codes, such as circuit elements and extensive properties of resistors. Secondly, I analyzed how students referred to these properties as part of the explanatory models they were co-constructing and refining. Specifically, I attended to how students: (a) posed questions about electrical phenomena; (b) collected and/or interpreted evidence about electrical phenomena; (c) constructed mechanistic models (Krist et al., 2019); and (d) collaboratively assessed the explanatory power of a mechanistic models. Finally, I analyzed the selected episodes for moments when students laminated gestures and other resources from the semiotic bundle (i.e., speech, inscriptions, or tangible experimental tools). Specifically, I used three dimensions of gesturing (McNeill, 2005) – deictic, iconic, and metaphoric (see Table 2.1) – as deductive codes for characterizing how students used gestures when communicating their observations and ideas about electrical phenomena; beats were excluded because they are primarily used for structuring and/or emphasizing talk, rather than communicating propositional nor topical content. I transcribed and analyzed instances when students used gestures in conjunction with the science artifacts and/or inscriptions (e.g., drawings) to communicate their ideas and reasoning (see Table 2.1). The combination of this three-step approach for identifying and articulating students' multilingual and multimodal translanguaging practices provided a robust way for understanding how the presence of and interaction with science artifacts supports students in making their ideas and reasoning visible to their peers. All data analysis procedures were approved by my university's Internal Review Board (IRB).

Table 2.1 Summary of Analytical Codes; (( )) denotes enacted gestures in the transcript

First-cycle codes	Second-cycle codes	Sample of coded data
Electric flow	*Circular motion*	"If you put all the pieces together it makes a circle of motion of energy that runs through the wires, through the battery, and through the light bulb."
	Clashing currents	"It [electricity] bounces off here *((points to both wires))* and it [electricity] goes *((tracing wires with fingers))* … goes all the way *((tracing wires with fingers))* … over here *((touches lamp))*"
	Local/section	"Energy can get go *through the thick line*"
Electrical resistance: Length	*Small*	"Because when I put a light right here, it was dimmer, and when I put a light right there it was lighter. So, I think that it depends on – if it's *short or long*."
	Big	
Electrical resistance: Width	*Thin*	"Energy can get stuck on *the thin line*"
	Thick	"If there is *more space*, the more energy goes through"
Dimension of gesture	*Deictic: concrete or abstract pointing*	"The energy comes through the wires *((touches one of the connected wires))* … and it would go right here *((touches where the wire is clamped to the lead of the lamp holder))*."
	Iconic: movements related to events and/or concrete entities	"If [the conductor is] fatter *((moves thumb and index fingers apart from each other))*, more electricity can flow faster."
	Metaphoric: movements related to abstract concepts	"The energy from the battery causes the whole thing to run *((moves hand in a circle above the complete circuit))* perfectly."

2.3.4 A Winding Funding Trajectory

I think it is important to pause here to recognize the number of resources (e.g., materials, time) it took to do all this work and the challenges I faced to implement the project satisfactorily. For context, the study I am sharing with you here comes out of my doctoral dissertation, which I decided to design and enact outside of the scope of my advisor's funded research projects – all focused on science education at the high school and university classrooms. While I was aware that designing and implementing my own study would be a heavy lift, as a graduate student I did not realize how much the success of research projects relied on the infrastructure that research funds afforded.

As a graduate student, securing external grants to fund my project was virtually impossible. For one, the National Science Foundation (NSF) does not have a specific program for funding advanced graduate students' research, perhaps under the assumption that their dissertation research should happen within their advisor's projects. Even the Graduate Research Fellowship Program (GRFP), the most lauded program for funding graduate students' research, requires that students apply within their first 2 years of graduate school, leaving dissertation work in the social sciences essentially out of the question. Moreover, certain professional associations and organizations, such as Spencer/NAEd and AERA, do offer dissertation-specific fellowships, but these opportunities most often are restricted to support the final stages of the dissertation, namely some final analyses and writing. For these reasons, I was ineligible for the kinds of external grants for funding the project design and implementation.

The internal funding landscape in my public university was not any more promising. Similar to national organizations, there were incredibly competitive dissertation fellowships from the graduate school, all meant to only support writing. The only option available to me was through the university's Center for STEM Learning (CSL), which had a solicitation for graduate students, post-doctoral fellows, and faculty (both tenure track and instructors) from the university to apply for funds that would support their projects related to STEM education. Specifically, these mini grants of US$750 were created "to maintain an infrastructure of institutional support in order to transform STEM education, support education research within and across STEM fields and departments." Funds could be used for equipment, conferences, workshops, research assistantships, and/or honoraria for speakers, but could not be used to refund incurred costs.

Despite applying months before I needed the funds to purchase the equipment, the review process was delayed by several weeks without any prior notification. Since the CSL would not refund any expenses, this delay forced me to push back the start of the Summer iteration by a month; the delay even jeopardized being able to run the eight-week, summer-long program I had designed and promised to the library administrators. After being reviewed by only one volunteer reviewer, my proposal was given a score of 19 out of 40 possible points. In their rationale, the sole reviewer thought that: (i) that the study served a "relatively small number of young children engaged in a voluntary after-school learning program;" and (ii) that, despite my dissertation being "a nice but narrow project, benefitting these young students and supporting a graduate PhD project" they were "not convinced this is what CSL should be supporting." The reviewer and CSL staff encouraged me to apply for the next award cycle in Fall, but by the time the deadline rolled around, I would have been beyond the half point of the third and final iteration of the study. This sole review pretty much shut the final institutional door for me to be able to secure funds for my project and offer the kind of learning experience I was hoping for youth in my community.

Fortunately, the funding journey did not end there. First, through an education officer at SparkFun, a local company focused on maker and computer science education, I secured a US$250 grant that covered a some of the CircuitScribe™ components. Additionally, through Twitter, I reached out to the lead material engineer that created the CircuitScribe™ pens and they gave me a hefty educator discount so that I could acquire the rest of the materials I needed for the project. Finally, my advisor was willing to cover the rest of the costs associated with purchasing circuitry materials. Her financial support made all the difference and allowed me to move forward with my study, without me needing to delay it any further due to lack of funding. By that point, the only expense that I had to cover out of pocket were a video camera, an audio recorder, a tripod, and a memory card I could use for collecting data, which I justified as a long-term investment.

2.4 Findings

Here, I share two illustrative episodes about the central role the material artifacts played in supporting a student's sense-making as she investigated electrical phenomena. I present evidence related to two analytical themes (electric flow and electrical resistance, see Table 2.1) that Yesenia (a Mexican-origin fourth grader) leveraged to explain how she thought electrical energy was transmitted through the circuit and how its flow was regulated by the circuit's elements. Specifically, I coded for the moments when Yesenia attended to how electricity flowed through the circuit, the features of electrical resistance she identified, and the gestures she leveraged to share her ideas and observations, particularly when combined with tangible artifacts (see Table 2.1).

2.4.1 Electric Flow: Electricity Moving Through a Wired DC Circuit

During her first visit to the program, I presented Yesenia and her younger brother with wires, bulbs, and batteries, and she was confident that they could successfully construct an electrical circuit. After making the bulb light up on their first attempt, I asked Yesenia to share with the rest of the group her explanation for how and why she thought the bulb lit up and stated:

> Excerpt 1: (Session 4; (( )) denote enacted gestures in the transcript)
>
> All batteries ((touches battery)) have energy and the energy from the battery causes the whole thing to run ((moves hand in a circle above the circuit)) perfectly. Energy comes from a type of iron. So, they put that iron in the battery and that makes energy. So, when the energy ((touches battery)) hits the wire, it goes through the wire ((runs a hand along the wire)), through the metal ((points to the lead of the lamp holder)) because energy can run through metal. So, it runs through the metal, and it reaches the lightbulb, and it causes the lightbulb to light up.

Yesenia's explanation began with an acknowledgement that electrical energy is pushed through the circuit by a battery in a circular fashion, as denoted by her moving her hands in a circular pattern above the circuit (i.e., a metaphoric gesture). Her initial statements also recognize that there is something special about batteries as circuit elements, specifically that they have a "type of iron" in them that generated the electricity that would eventually enter and flow through the circuit – perhaps she was thinking about the anode and cathode inside a battery that create the necessary potential differential. In Yesenia's model, the electricity would move through the wires and into the lamp, which Yesenia depicted by running her hand along the wire (i.e., a metaphoric gesture) and then pointing to the metallic part of the lamp holder (i.e., a deictic gesture). Throughout, Yesenia attended to the circuit's metallic elements, which were relevant to her because "energy can run through metal," implying that not all objects have electrical energy to flow through them.

Yesenia's model for explaining how and why electricity moved through the circuit was detailed in many ways. First, it accounted for all the relevant elements involved in making the bulb light up and what was their particular contribution to this process: from the battery providing and pushing energy through the circuit, to the metallic nature of the wires and other components. Additionally, Yesenia's explanation was anchored in a semiotic bundle that laminated speech, gestures (in this case both deictic and metaphoric), and the tangible circuitry artifacts. Specifically, rather than only saying, "it goes through the wire," Yesenia also performed a gesture above the wire to visually represent how she thought a nanoscopic process that is imperceptible to human eyes unfolded. Without either of these three elements, Yesenia's model would have been incomplete or ambiguous, at best, defeating the purpose of how productive explanatory models can support students co-construct knowledge about natural phenomena.

These kinds of laminations of speech, gestures, and artifacts slowly crystalized into semiotic bundles with their own meaning and eventually acted as short hands for referring to specific ideas and/or phenomena. For instance, shortly after presenting the above model, Yesenia offered the following explanation when another student asked her why the light bulb turned on:

Yesenia's explanation began with a combination of speech and gestures that illustrated how electricity moved in a circle (Fig. 2.1, Line 1). While brief, this first statement shows how integral gestures are to Yesenia's communication, specifically by how expressive gestures became for communicating that electricity flowed in circles. Yesenia then added that electricity flowed rapidly, as she quickly moved her right hand in a circular motion, completing three circles in a handful of seconds (Fig. 2.1, Line 2). Yesenia conveyed two messages about the electricity through these gestures: she illustrated that electricity traveled in a circular path through an imaginary circuit (one she did not reference in her speech), and that the electricity traveled through it very quickly. She completed a similar set of gestures a few seconds later, as she demonstrated how electricity would move up to the bulb from the wires (Fig. 2.1, Line 3) and reasoned that the electricity's speed played a role (Fig. 2.1, Line 4). Yesenia, once again, moved her hand in a circular motion to represent the electricity that flowed through the circuit, even if she did not explicitly mention the electricity's path (implicit in the directionality of her gestures).

It is important to highlight how Yesenia performed this gesture with her hand suspended in the air, differently from how she had traced the wires of the tangible circuit. Moving her hand in a circle far from the wires indicates that Yesenia had abstracted this gesture from the circuit artifacts, allowing her to reference and illustrate how electric energy flowed through a hypothetical circuit. Developing and performing a gesture abstracted from science artifacts when referring to a physical process was a significant step in Yesenia's conceptual understanding of electric

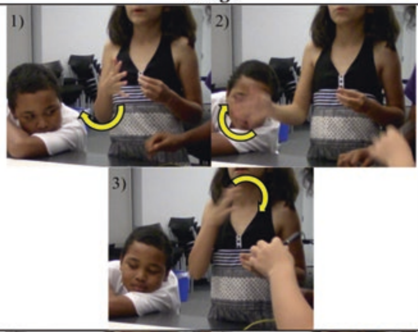
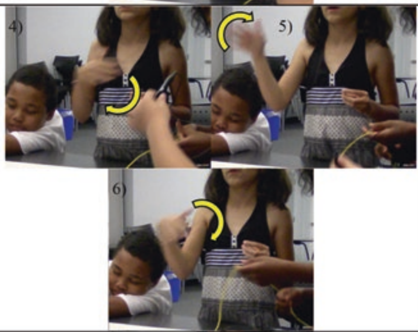
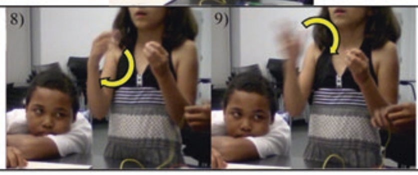
Line	Time	Utterances	Image
1	01:18	Energy is ru –	
2	01:19	It always runs very quickly.	
3	01:22	And so… it makes the light bulb…	
4	01:25	light up because it's going so quickly you can see it…	

Fig. 2.1 Yesenia represents electric flow in a DC circuit through gestures (Session 4; Yellow curved arrows represent circular motion and its direction; Red arrows represent hand is stationary)

flow, showing how she could move between concrete experiences and abstract principles. Moreover, Yesenia had leveraged a set of semiotic bundles that she would deploy depending on what the sense-making needs were: when referring to electricity flowing through a tangible circuit and highlighting the salient elements, she touched different parts of the circuit and traced the wires with her hand; when she alluded to electricity running through a pretend circuit, she moved her hand in a circle in the air, without singling out specific elements.

2.4.2 *Electrical Resistance: How the Conductor's Geometry Regulates Electric Flow*

The scope of Yesenia's concrete gestures for illustrating electricity moving through a circuit extended to her explanations about how the width of the conductive lines affected electric flow. For instance, when Yesenia observed that the bulb would not light up when connected to a mixed-width circuit (one thick line and one thin line), she reasoned that maybe there was not enough electricity reaching the lamp. When I asked her to elaborate, she added:

Yesenia started by laminating a deictic gesture (pointing to the line), a metaphoric gesture (electric flow), and the drawn circuit to represent how electricity could flow through the thin conductive line (Fig. 2.2, line 1). Yesenia then explained how the wide line's thickness allowed electricity to flow through it (Fig. 2.2, line 2), an idea she represented by running her finger up and down the line (i.e., simultaneously deictic and metaphoric). She further clarified that the electricity could run through the wide line in either direction: toward the battery (Fig. 2.2, line 3), as she ran her finger along the line in that direction (i.e., metaphoric gesture); or away from the battery (Fig. 2.2, line 4), as she ran her finger in the opposite direction (i.e., metaphoric gesture). Finally, Yesenia contrasted the thin and wide lines based on how she thought they regulated the electricity's flow, claiming that the former was too small for the electricity to move through it (Fig. 2.2, lines 5–6) and, therefore, there would not be enough electricity to turn on the lamp. In summary, Yesenia presented a sophisticated model for how the transmission of electrical energy is dependent on the geometric (i.e., extensive) properties of conductors, going beyond the limited binary of classifying objects as insulators or conductors solely based on their material composition.

Yesenia's gesturing about electricity flowing through the conductive lines was made concrete, leveraging the semiotic bundle composed of speech, gesture, and circuit artifacts, making her ideas visible. Just as before, Yesenia used deictic gestures for identifying and disambiguating the circuit elements she was referring to, pointing to the parts of the drawn circuit she was addressing (e.g., the wide line). Additionally, Yesenia used metaphoric gestures for communicating how she thought the electricity would travel through either line of the circuit, making it clear for others how she thought this process took place. However, this concrete version of her "electric flow" gesture was different from the ones she used before with the wired circuit. Specifically, Yesenia had represented electricity flowing through a circuit via moving her hand in a circular motion directly over the physical circuit (see Excerpts 1 and 2). This time, Yesenia did not concern herself with whether or how electricity flowed through the whole circuit. Instead, Yesenia focused her attention on the conductive lines, and her gestures were limited to tracing each line when illustrating electric flow through each one (e.g., running finger along the thin line). Performing a more localized version of the "electric flow" gesture, once again, suggests that Yesenia was intentional about choosing a hand motion that fit the material artifact and her communicative goals, rather than using a one-size-fits-all gesture

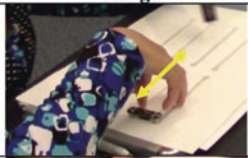
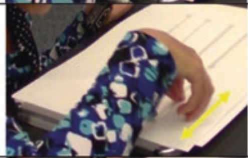
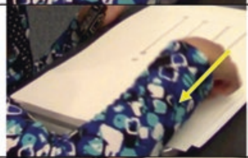
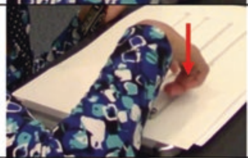
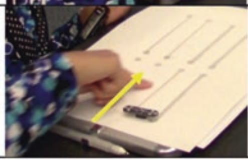
Line	Time	Utterances ((gestures))	Image
1	33:38	Maybe because this one ((runs finger several times up and down thin line))…	
2	33:43	… because this one is thicker and there can be electricity through it ((runs finger several times up and down wide line))	
3	33:50	Like, the electricity can go this way ((runs finger along the wide line, towards where the battery would be)) …	
4	33:51	Yesenia: … or that way ((runs finger along the wide line, away from where the battery would be)) …	
5	33:53	Yesenia: … but maybe the electricity could get stuck on this one ((points to thin line)) because it's small and too tight.	
6	34:00	Yesenia: And, so, maybe it can't go through here ((runs finger along thin line, towards where the battery would be)) … all the way back.	

Fig. 2.2 Yesenia represents electric flow through conductive ink through gesturing over the drawn circuits – (Session 8; Yellow arrows represent motion and its direction; Red arrows represent hands are stationary)

that could be ambiguously interpreted. Yesenia enacting a specific version of the gesture reinforces the importance of the presence of science artifacts can be for supporting emergent bilingual students to communicate their observations and explanations about electrical phenomena. The tangible tools not only provided a ground for Yesenia's deictic and metaphoric gestures, but also seemed to guide her decision of which type of gesture she would use to effectively communicate her ideas.

2.5 Discussion and Implications

In this study, I set out to understand how a young EBS laminated speech, gestures, and science artifacts as part of her translanguaging practices when sharing her explanatory models about electrical phenomena. Through analyzing video recordings of Yesenia investigating and explaining the transmission and transformation of electrical energy, it became apparent that she leveraged on multiple semiotic resources when observing and sharing her insights. Moreover, Yesenia relied on the science artifacts that she used to conduct her investigations to communicate her thoughts more efficiently, allowing her to represent nanoscopic processes invisible to the eye. These findings indicate that Yesenia drew from her larger semiotic repertoire when engaging in meaning-making practices, such as constructing evidence-based explanations, without adhering to sociopolitical hierarchies that presume one form of languaging being more valuable than another.

2.5.1 Affordances for Problematizing Conceptual Features of Electrical Phenomena

The science artifacts played a crucial role in supporting students to investigate and understand electrical phenomena, making visible and bringing to the students' attention salient conceptual features about electrical phenomena they needed to consider. These artifacts were flexible in allowing students to investigate their own questions and could quickly make changes to their experimental setup to pursue further questions. When Yesenia used traditional circuit tools (e.g., wires, lamps), her investigations and explanations focused predominantly on electricity moved freely through them. This is evinced in Yesenia's attention to how electricity flowed through the circuit and ignoring what kinds of elements and/or properties would stop or decrease the electric flow; after all, conventional wires and lamps are seldom designed to make electrical resistance visible. Introducing conductive ink, on the other hand, supported students' exploration of how the conductive lines' geometry affected the flow of electricity through the circuit. Specifically, because of how the conductive ink could be easily altered, and because it provided students with immediate feedback on the effects of those changes, students could relate the changes in the geometry to the brightness of the lamp, allowing them to propose general principles how for the lines' width and length affect electric flow. Therefore, the conductive ink was effective at making the conductors' extensive properties visible for students to investigate and problematize, crucial for developing a conceptual understanding of electrical resistance.

2.5.2 Affordances for Communicating About Electrical Phenomena

Throughout the program, students used multiple dimensions of gesturing when communicating their ideas, most of which were laminated with and disambiguated by the science artifacts they were investigating. In all of the tasks that they engaged in, students leveraged multilingual, multimodal, and multisensory semiotic resources when presenting and engaging with other's ideas and reasoning. Moreover, gestures played an essential role in supporting students to share their thinking effectively and in ways they seemed comfortable with.

The two main dimensions of gestures that she laminated with the investigation materials (i.e., deictic and metaphoric) seemed to serve distinct functions when she shared her explanations. The specific function of different dimensions of gestures was best illustrated by Yesenia's different versions of the "electric flow" gesture she enacted throughout the program. When referring to and talking about a given physical circuit (either wired or drawn), Yesenia relied on both deictic and metaphoric gestures to identify the salient circuit elements and describe the processes these elements were involved in. Whereas, when referring to an imaginary circuit, Yesenia only used metaphoric gestures to illustrate how directly flowed through the circuit. The differences in how Yesenia used the various dimensions of gestures ratifies the communicative functions deictic and metaphoric gestures had, suggests that students are intentional in choosing the most appropriate semiotic bundles to meet their discursive needs; without access to her gesturing, her contributions would have been limited and more challenging to interpret accurately. Therefore, as the literature on translanguaging through materials structures suggests (Pennycook, 2017; Zhu et al., 2017a, b), students' movements of limbs anchored in science artifacts became primary ways for them to communicate their observations and models of electrical phenomena.

While all the gestures described above served important roles when students shared their ideas and reasoning, it is difficult to overstate how crucial the tangible science artifacts were for supporting students' gesturing. First, students used deictic gestures to highlight the circuit elements and/or features they wanted to talk about but may not have had ways of expressing through speech, especially in academic English. Therefore, a tangible artifact could be used as a semiotic sign in and of itself, allowing students to communicate only through referencing it. Additionally, just as the tools themselves could convey meaning, students could use them when gesturing in order to disambiguate their ideas. Rather than having to clarify, students could just point to or move their hands over various circuit elements as they shared their thinking. Thus, science artifacts served as a ground against which students' speech could be complemented and/or disambiguated when communicating their observations and reasoning about electrical phenomena. Finally, the reciprocal and productive relationship between speech, gesture, and artifacts reinforces the importance of having access to a robust semiotic bundle for supporting students' communication. Had either of these of the semiotic resources been missing, or purposefully excluded from the learning environment, an important communicative resource (linguistic or not) would have been taken away, limiting how students could have shared their reasoning and co-constructed meaning.

2.5.3 Science Artifacts Can Create Equitable Opportunities for Learning Science

The episodes I presented here exemplify how Yesenia engaged in productive disciplinary practices of science, like asking questions about electrical resistance (e.g., how does the width of the line affect electric flow?), planning and implementing investigations (e.g., "we can make the lines as fat or as thin as we want to"), and presenting evidence-based mechanistic models that explained their observations. At the same time, the tangible experimental tools served as supports for her to share her ideas and reasoning by leveraging a wide range of multilingual, multimodal, and multisensory semiotic resources. Her case is representative of how participating students frequently made use of multiple dimensions of gestures for sharing their ideas and observations, most often in relation to the tangible science artifacts that were present in the learning environment. Based on these findings, I argue that the presence of the science artifacts provided opportunities for students to communicate their ideas through productive and accessible semiotic bundles. Moreover, these investigation tools helped broaden the range of semiotic resources that were valued in the learning environment and increased the communicative entry points for emergent bilingual students to investigate natural phenomena.

Through the analysis presented here, my goal is to exemplify how the tangible science artifacts can simultaneously serve a double-function in science learning environments: making visible important conceptual aspects of the natural world for students to problematize, and support students to make their thinking and reasoning visible to others. And while both of these broad roles could be used in most science learning environments in ways that can benefit a wide range of students, I argue that tangible tools could be important levers when designing equitable and inclusive science learning environments, especially for EBS. Specifically, as demonstrated in the analysis, tangible tools can create opportunities for students to engage in science disciplinary practices in order to problematize and author knowledge about the natural world, opportunities which, as many have reported, are seldom available for students from underserved communities (Rodriguez, 2015; Vossoughi et al., 2016). Moreover, simply making these material resources available may not be enough to disrupt the ideologies and pedagogies that undergird injustices in science learning environments, as (Rodriguez, 2015) argues in his analysis of an educator trying to make the most of a constraining and under-resourced curriculum.

For the inclusion of science artifacts and other material resources to create equitable opportunities for learning science, I argue that two conditions need to be met. First, educators and/or curriculum developers must clearly articulate the rationale behind including certain artifacts, how the design features of these artifacts allow or constrain specific forms of collective sense-making, and the kinds of tasks and participant structures through which these artifacts will mediate learning. Second, I think it is important to support educators, particularly pre- and in-service teachers, in recognizing the power of science artifacts in creating equitable learning opportunities for EBS and other marginalized learners. Specifically, professional learning opportunities should support educators in identifying and dismantling the deficit-based perspectives they may articulate and enact towards historically minoritized students. Relatedly, professional learning should support educators in recognizing how science artifacts can invite students into rich intellectual activities that build on their conceptual and semiotic resources.

The promise of tangible investigation materials for making science education more equitable for emergent bilingual students comes with the reminder of how difficult it was to fund this project. There were many opportunities along the way when I may not have secured the funds to purchase the science artifacts that would support EBS do the kind of intellectual work I presented here. Without the small SparkFun grant and my advisor's help, I might have been forced to charge families for the program in order to cover costs, which might have resulted in making the program less accessible to working-class families, defeating the goal of wanting this to be an equitable science learning opportunity. Finally, if I had not been able to pay for my own research equipment (already a feat on a grad student salary), I would not have been able to collect as much, or any, of the data that I have shared with you here. I often wonder how many more children I would have been able to serve, had I been eligible to apply to external or internal funding sources that actually covered the expenses and efforts related to study design and implementation. I would like to think that my research and the manuscripts I write will impact the number and quality of science learning opportunities for emergent bilingual students; at the same time, these kinds of academic products do not really address the immediate material needs of minoritized children and their families, which is why to me it is also paramount to secure resources to do so. I also wonder if the CSL reviewer would still think that this project was too narrow and did not meet the institute's vision. Either way, it is long overdue that we create better funding mechanisms for supporting graduate students (and early-career scholars) that give them the freedom to design and implement their own studies, addressing questions that perhaps their advisors' projects are not able to sustain.FundingThis study was in part possible due to a generous small grant from SparkFun and the support of CircuitScribe.

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Chapter 3
Fostering Social Connectedness and Interest in Science Through the Use of a Sports Model

Sheron Mark, Matthew Trzaskus, Lauren Archer, and Peter Azmani

In this study, a group of high school biology teachers collaborated to design instructional units that centrally focused on sports and physical activities. Through action research, the impact of teaching science in this way on students was investigated to inform future implementation. Sports were considered for this purpose as many young people are engaged in sports formally and informally. Formal involvement may include being part of teams and training programs within or out of school. Informal involvement may include playing for fun outside of school, individually or with friends and family. Informal involvement may also include attending sports events or watching sports broadcasts.

Sports have significant potential in creating positive learning environments for students (Giulianotti, 2012). Specifically, sports can support collaboration and team/group solidarity, new social connections, creative self-expression, and active

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learning. As widespread engagements among students with diverse interests and backgrounds, sports and physical activities can provide students with productive resources upon which educators can build to design engaging and impactful instruction. Such work has been accomplished in science education, across K – 12, whereby students have developed conceptual understanding and scientific skills by learning through sports and physical activities (e.g. Hechter, 2013; Lemaster & Willett, 2019); however, the impact of teaching science through sports and physical activities on students' social gains, particularly social connectedness to their teacher and peers, has been less addressed. The emphasis has remained on (formal) curriculum-defined academic gains as opposed to these gains in social connectedness in and of itself, especially in educational contexts primarily serving students of color.

Some researchers have investigated the impact of social connectedness on motivation and learning. For instance, Ryan and Deci (2000) have focused on *relatedness*, defined as "the need to feel belongingness and connectedness with others" (p. 73). This social connectedness to a learning environment, such as a classroom or subject area, can support students' self-driven desire to participate in learning (Ryan & Deci, 2000). In science education, culturally diverse students, particularly students of color in low-income, urban school settings, have been historically underserved due to a lack of high-quality curriculum and instruction as a result of cultural dynamics and institutional structures in education (Brown & Spang, 2008; Rodriguez, 2015; Thadani et al., 2010). As a result, many culturally diverse students in urban science education may face challenges such as significant gaps or lack of connectedness between themselves and school-sanctioned ways of being scientific or between themselves and their teachers. In classroom contexts where students' perceptions of social connectedness with their instructors were higher, motivation to participate in learning was higher (Hewitt et al., 2019). Additionally, Lin-Siegler et al. (2016) investigated the impact of aiding students to relate more authentically to science, specifically through stories of struggle and overcoming challenges. They found that this was effective in improving motivation and learning, especially for those students who were performing at lower levels, and this was as a result of students' feelings of connectedness to the stories and the scientists who struggled. Conversely, if there is a lack of social connectedness to science and/or science teachers, this may limit students' motivation to engage in science in formal school settings.

Additionally, much of the science education literature reviewing teaching through sports and physical activities has focused on high school and university-level physical sciences (e.g. Starling & Starling, 2017; Widenhorn, 2016), reflective of higher-level science courses and higher-performing, more intrinsically motivated science students. White males of higher socioeconomic backgrounds and higher parental educational backgrounds tend to be overrepresented among students in these areas of science study (National Science Board, 2018). In urban science education, particularly regarding students of color from low-income settings, who have been historically underserved in formal science education, there is great need to work towards improving the quality of science education in more general and introductory science courses, such as biology. Improving these foundational courses may further support a more diverse pool of students in accessing more advanced science courses and post-secondary science study and career participation. This work can, therefore, contribute to extending teaching science through sports and physical activities into other science disciplines, into a wider array of courses, and in ways that are successful for students who are more academically and culturally diverse.

Therefore, this study sought to explore how to build upon the resources of sports, as diverse and widespread engagements, to support social connectedness within a culturally diverse, urban science education setting. To this end, a group of students who had been historically underperforming in science in an urban school setting had the opportunity to learn high school biology through lessons centered on sports. These students were interviewed following these experiences to solicit their perspectives. The focus of the study was gains in social connectedness among students because of learning science through sports and physical activities. Student gains in curriculum-defined knowledge and skills solely or primarily as a result of the sports-focused lessons, distinct from more traditional instruction, were not investigated but will be in future efforts. The choice to focus on social connectedness in the science learning environment, in and of itself, and not on the curriculum-defined learning goals certainly presented challenges to the publication of this research study. The assumption underlying the study's purpose was that, if students are positively engaged and intrinsically motivated, then high quality, deep learning will be supported. This edited book as a venue for this research has provided a unique and timely resource in maintaining this desired study conceptualization and focus.

3.1 Literature Review

3.1.1 Educational Potential of Sports

Sports are particularly effective for education as they are incredibly diverse and widespread, existing globally with all cultures having some local forms of sports (Giulianotti, 2012). Sports are versatile, cost-effective tools for education as they are popular and appealing, especially to young people, with participation ranging from performing to observing (Marshall & Barry, 2015). Many sports can be played with little or no equipment or at minimal cost, requiring only a ball, for instance. Additionally, with formalized school and community sports programs already established within many places and institutions, classroom teaching through sports can build upon these foundations. Thus, as a resource for teaching, sports can be familiar, and easily implemented, and readily relatable to students of diverse interests and backgrounds.

Sports additionally foster social connections and communication among diverse individuals (Giulianotti, 2012; Marshall & Barry, 2015) Therefore, teaching through sports may support students and teachers in developing a socially connected learning environment. When individuals experience social connectedness while engaged in activities, such as classroom teaching and learning, they experience greater motivation (Ryan & Deci, 2000). Additionally, sports can provide students with access to an achievement setting where they have or can develop competence and experience success (Ettekal et al., 2018; Marshall & Barry, 2015). Including opportunities for student growth and accomplishment through sports in the traditional academic setting of the classroom can be particularly beneficial for students who have been disengaged or uninterested in the subject area or for those students who have struggled to learn targeted concepts and skills. With sports serving as the context of instruction and learning experiences, students may feel confident in their sports-related knowledge, interests, and skills and may be more motivated to participate in learning activities. Like social connectedness, these feelings of confidence in one's ability to successfully perform a task increases motivation (Ryan & Deci, 2000).

3.1.2 Science Knowledge and Skills Development Through Sports

Research has reported on science teaching and learning through sports and physical activities. For instance, the fastest score ever made in Junior League rugby served as a physics model for students to learn about aerodynamics and the relationship among factors such as ball size, drag, and athlete speed (Goff & Lipscombe, 2015). Students analyzed the distance that the ball landed after kickoff and the "hang time" of the kick to determine the initial launch speed and angle. Hechter (2013) described an inquiry activity focused on learning about position-position and position-time relationships represented in graphical displays in which students observed and recorded data on the movement of an ice hockey puck when passed by an athlete. Students then generated graphical plots by hand and using technology to represent the motion and positionality of what they observed. They then compared the recorded motion to what they predicted.

From a conceptual change perspective, sports and physical activities can aid in engaging students' naïve scientific conceptions and mental models, thereby helping to overcome barriers to changing flaws in conceptual understanding (Ennis, 2007). Thomas and Quick (2012) discussed where students learned about surface gravity on planets based on relative position in the universe by hitting baseballs with bats and recording the "hang time" of the balls. They calculated the average "hang time" under Earth's gravitational conditions and converted those data to determine the "hang time" on other planets using respective gravitational acceleration data. Playing baseball provided the opportunity to collect meaningful data, which served as a mental model to support the targeted conceptual understanding.

Several other researchers explained how sports "plays" or specific athletic performances within games can be deconstructed and understood in scientific terms.

For instance, Widenhorn (2016) geometrically analyzed 22 attempted penalty kicks in an American soccer game to determine the conditions for which the ball ricocheted off both of the goal posts resulting in failed goals. Starling and Starling (2017) proposed that students can apply scientific understanding and skill to determine the ideal range at which a baseball umpire should stand to make an accurate call about whether or not a baseball player has made it to the base in time. Their analysis focused on real-life data from a professional MLB game and involved multiple physical science variables that would impact the umpire's capacity to make the accurate determination, including the speed of sound and light, index of refraction, and temperature.

3.1.3 Student Social Gains Through Sports

Beyond student gains in science knowledge and skills, efforts in teaching students through sports and physical activities have improved social outcomes for students. This research is well-represented in physical education and sports pedagogy; however, in science education this work appears to be lacking. Garrett and Wrench (2018), for instance, were able to support greater student engagement in dance education for male students from socioeconomically disadvantaged backgrounds. Specifically, efforts were made to improve the inclusion of boys' bodies, interests, and backgrounds in dance classes. By connecting dance to the larger life experiences and interests of male students, they sought to support the expansion of conceptions of masculinity for the young men. Other educators have cultivated positive social behaviors and interactions among students, including respect for peers, good sportsmanship, encouragement and appreciation for others, and active and on-task behavior, through teaching in sports-based contexts (García-López & Gutiérrez, 2015; Samalot-Rivera & Porretta, 2013; Vidoni & Ward, 2009).

3.1.4 Power, Privilege, and Identity in Sport Settings

While there is immense potential to support social gains among students by teaching through sports and physical activities, there exist historical hierarchies and marginalizing ideologies embedded within sports, health, and physical activity contexts. These can be potentially harmful to students' experiences and identity development, counteracting social connectedness and other social gains. Additionally, students' peer interaction in sports-based contexts, like formal classrooms, are vulnerable to the effects of differential power and status and can contribute to privileging or marginalizing students (Brock et al., 2009). Power and status may be influenced by race, ethnicity, income, ability, and other aspects of identity. Therefore, educators must be cognizant of these ideologies and social interactions when teaching through sports and physical activities.

For instance, Tischler and McCaughtry (2011) documented how several male students' masculinities were marginalized as a result of the content, pedagogical practices, student-teacher relationships, and peer social cultures in physical education. Similarly, female students have historically encountered interpersonal and institutional barriers to equitable participation and development in sports and physical education, including feeling "less comfortable" and having negative perceptions of their bodies and physicality (Azzarito & Solmon, 2006); "patriarchal ideologies and patterns of gender differentiation" (Nilges, 1998, pg. 176); and gendered differences in teacher-student interaction within sports/physical education-based settings (Nicaise et al., 2006). Race-based ideologies exist within sports, as well. Black students, especially Black males, are overrepresented in sports (Harper et al., 2013). Furthermore, negative stereotypes about their aggression, athleticism and intellectual inferiority are widespread (Harrison & Lawrence, 2004; Sailes, 1993). Engaging sports and physical activities to teach in culturally diverse settings is a complex and sensitive undertaking, therefore understanding ways to support positive student experiences and social outcomes is of even greater interest to the authors.

Overall, from a review of the literature, research efforts in teaching through sports and physical activities have emphasized gains in student knowledge and skills in advanced physical science courses with student social gains and life sciences being less addressed. These two latter areas are the focus of the current study. A model for pedagogical approach is first presented. This model was implemented with a group of culturally diverse high school students who varied in terms of race, ethnicity, gender, and sport affiliation/involvement. The research question guiding the study was:

> In what ways does teaching biology through sports and physical activities support social connectedness and other social gains among students who are culturally diverse, as well as variably interested and involved in sports?

3.2 Research Context

In 2016–2017, a team of high school biology teachers developed a lesson using basketball to teach aspects of natural selection and adaptation. One teacher was a White male, one was a Middle Eastern male, and two were White females. All were English-speaking and were teaching science for less than 5 years. While the teachers collaborated to develop the lesson, the present study focused on one class taught by the White male science teacher, Mr. Tony. Mr. Tony and all other names in the chapter are pseudonyms. Mr. Tony and one of the female teachers, Ms. Jane, were also part of the research team, along with a Black, English-speaking, Caribbean female as the lead author. The teachers' roles in research focused on the development of the lessons, data analysis, and co-writing. The lead author was active both at the school in which the science lessons were being implemented and at the university, where she worked with a doctoral-level graduate research assistant who identified himself as an African American male.

Mr. Tony's class was one in which students were assigned after having failed previous science classes or having been identified as being behind in grade-level science coursework. Historically, student performance, engagement, and motivation in science in this class tended to be low. Thus, fostering social connectedness through a novel instructional approach may be fruitful in transforming the science learning environment for these students. Action research (Stringer, 2008) supported the authors in systematically collaborating and reflecting on the instructional approach being explored in the high school classroom in order to derive sound understanding to revise and improve the efforts.

The school was located in a medium-sized urban center in the Southeast United States. The school may be, furthermore, characterized as large and culturally diverse. In 2016–2017, 1322 students were enrolled in the school. Enrollment included approximately 42% Black, 36% White, 16% Latinx, 3.2% bi/multiracial, 3% Asian, and 0.3% American Indian or Alaska Native students. Approximately 81% of the students were eligible for free or reduced lunch indicating a high level of representation of lower-income status. Approximately 12% of students were identified as English learners, 13% enrolled in special education, and 12% were experiencing homelessness.

3.2.1 The Instructional Unit: Teaching Natural Selection and Adaptation Through Basketball

The student learning activities took place on a basketball court and later in the classroom. On the basketball court, students engaged in activities to represent a population of organisms in a "basketball" ecosystem. Each individual student represented an organism, while all the students collectively represented the population. In this ecosystem, students would attempt to score baskets, which represented attempts at survival. When students successfully scored baskets, this represented survival of the organisms they modeled. Meanwhile, failed attempts represented death of the organisms. Students all attempted the same type of basket, e.g. a one-handed shot made by jumping near the hoop (i.e. a lay-up), a two-handed throw from an assigned location on the court, or a shot made from the three-point line (semi-circle boundary surrounding the hoop). Multiple hoops were available, so students attempted different kinds of baskets at each hoop. The students attempted the baskets while being variably aided or limited by behavioral and physical factors, e.g. attempting a basket while kneeling (i.e. a physical limitation), while standing on a step-ladder (i.e. a physical aid), or while having the ability to ask a more skilled friend to attempt the basket for them (i.e. a behavioral aid). These behavioral and physical factors or "traits" were randomly assigned to students by drawing cards out of a container. In so doing, traits varied among the students and represented a model of randomized trait diversity among a population as it would in nature. This trait variation was expected to lead to differences in performance (i.e. success or failure in scoring baskets) among individuals in the model population of the basketball ecosystem. The influence of students' skills in playing was recognized as a limitation of the model, i.e. students' own skills in basketball might aid or limit them just as the traits assigned to them; however, this served as an authentic opportunity to discuss with students how scientific models do have limitations in how they represent natural phenomena.

Later instruction built on this activity to explain this trait variation as having been derived from genetic diversity, i.e. the genetic makeup or genes of each organism was different. Additionally, the expression of those genes differed. Gene expression corresponds to what kind of proteins are produced, when, where, and in what combination. Proteins have a multitude of functions relating to structure, function, and performance of organisms. Therefore, diversity in genetic makeup and gene expression influence the physical and behavioral traits of organisms. These traits then influence organisms' chances of survival.

The assigned traits were listed on a class-wide data sheet and the results of students' attempted baskets were recorded as depicted in Fig. 3.1. As above, there are additional limitations important to be understood by both educators and students engaging in this classroom model of evolution. The first important limitation is that this model reflects the unfolding of *survival of the fittest* amongst non-human animals in the wild. While physical and behavioral limitations can severely impact the chances of survival of animals competing to survive in the wild, this does not translate directly to human social systems. While there is a diversity of physical and behavioral characteristics amongst humans, the capacities of humans to adapt challenges a simple analogy of success in one specific task, i.e. scoring baskets, equating to quality of life and survival. This is an important distinction to reinforce to the students as they model these systems.

Relatedly, the second limitation present in this early iteration of the model is the language used to describe the physical and behavioral characteristics. While traits such as size, speed, and senses can affect animals' competitive chances in the wild, amongst humans these traits are not so deterministic. More importantly, diversity in physical and behavioral characteristics within human systems have and continue to be very politically weighted. As such, language used to describe these traits can support or limit efforts towards culturally-responsive and equitable education. Unfortunately, some of the language used to describe the traits modeled in the system is problematic as it bluntly states real human physical traits as disadvantages, e.g. "armless" and "blind." As stated earlier, within human systems, human capacities allow for greater adaptation in response to diverse physical and behavioral characteristics to overcome, rather than be limited by, disadvantages. Thus, this instructional unit did suffer in this earlier iteration from problematic language choice and insufficiently addressing key distinctions between the human systems within which we live and the animal systems being modeled.

A green sticker indicated a successful basket and, therefore, survival; while a pink sticker indicated a failed attempt and, therefore, represented organism death. Students attempted baskets multiple times and, for each attempt, either a pink or green sticker was used to indicate the outcome. After attempting their baskets,

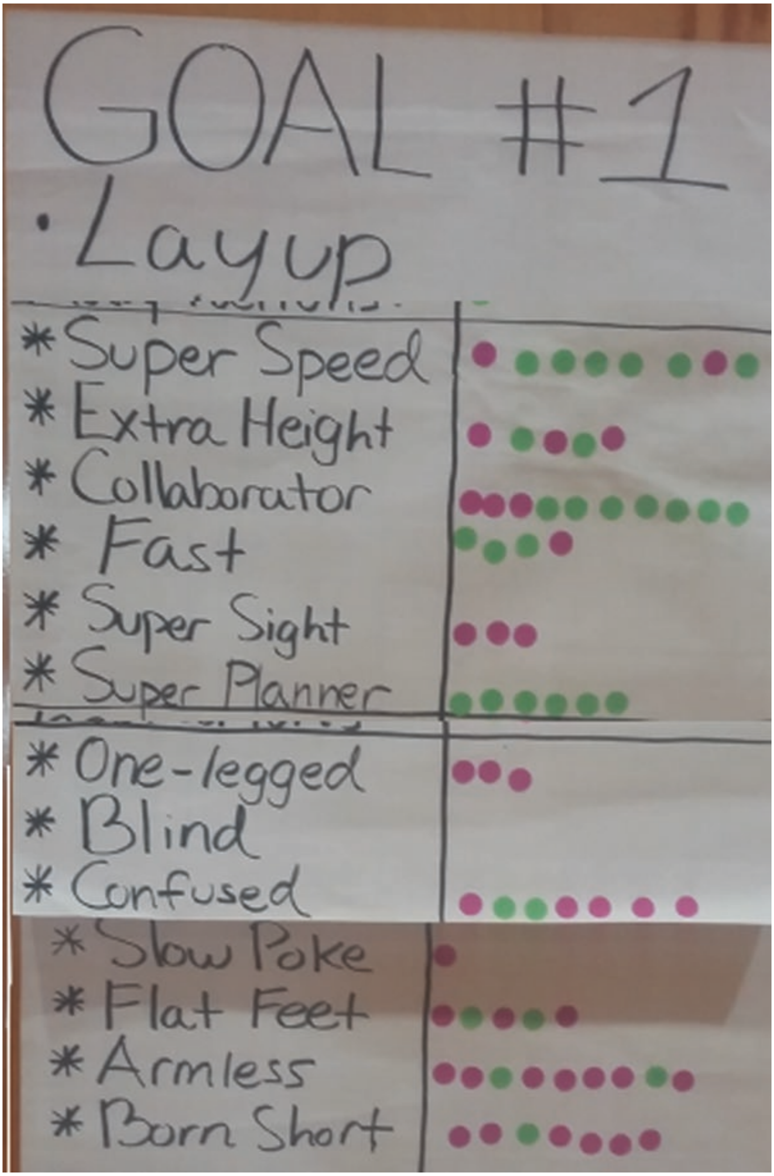

Fig. 3.1 Class-wide data collection

students could then also draw another trait out of the container and attempt baskets differently as required by that trait. After collecting data, but prior to data analysis, Mr. Tony and one collaborating teacher, Mrs. Harriett, structured in an optional activity where students chose to play team basketball with them in teams of three. Mr. Tony and Mrs. Harriett played on a team with one other student and this team played against another team of three students. The students took charge of team selection. After these two teams of three played against each other, several other students participated taking turns forming teams. Other students not interested in this additional game play and physical exertion watched as spectators.

This opportunity to play team basketball was for fun; but the teachers would also later use students' self-selected teams as an analogy for sexual selection. Specifically, the teachers would explain that some students knew who was more or less skilled in basketball or students would look at physical characteristics, such as height, speed, and prior performance in the activities. In trying to choose team members who would likely help them win, these perspectives would have likely influenced students in picking their teams. The teachers explained that that decision-making was analogous to organisms selecting mates for sexual reproduction based on cues indicating which organisms were more attractive, healthy, or fit. As with the earlier discussion of limitations, there are important distinctions between this model of sexual reproduction in animal systems and more complex human social relationships involving personality characteristics (Botwin et al., 1997) and other significantly politically weighted cultural factors (Cellio, 2008). Thus explicit conversations about limitations of the model should take place with students to avoid establishing problematic misconceptions.

Following student data collection, students engaged in analysis by seeking out trends in the data and shared in a whole group setting. Mr. Tony facilitated this whole class sharing out in order to encourage students' first-hand data analysis (rather than the teacher doing the sense-making on behalf of the students). Additionally, by sharing and discussing the data collectively, the teachers and students can confirm accurate student observations of trends and, further, can correct or clarify incorrect observations of trends. This whole group discussion was important to communicate to students that the basketball activity was important scientifically and not just an enjoyable physical engagement, i.e. that their scoring attempts were to aid in their scientific sense-making and that, importantly, the students themselves were all capable of engaging in that scientific skill. Whole group format also supported peer collaboration and students learning by listening to and building off each other's observations.

Following the lesson detailed above, which involved using basketball shooting attempts as a model for adaptation and natural selection, a second lesson focused on biomechanics and American soccer was implemented. For this lesson, the students selectively limited their use of limbs when attempting to kick a soccer ball as far as possible, e.g. maintaining both arms stiffly at their sides and not bending their standing leg when kicking the ball. This lesson helped vividly illustrate for students the interconnectedness of the musculoskeletal system as they came to realize how they engaged so many limbs and body parts in preparing to effectively kick a ball. Previously, the students would focus only on movement involving their kicking leg. As with the optional opportunity to play team basketball with their teachers, Mr. Tony also provided free time to play team soccer with interested students at the end of the lesson.

3.3 Data Collection and Analysis

To investigate the impact of these lessons on fostering social connectedness in this science learning environment, interviews from a sample of students from Mr. Tony's class were conducted and their interview responses were later analyzed. The students represented variable levels of interest and involvement in sport, as well as gender, racial, and ethnic diversity. None of the female participants were interested or involved in sports at the time of the study, while the three males were. This is a recognized limitation of the study, as well as the sample size. Table 3.1 lists the participants, as well as their self-identified race, ethnicity, gender, and affiliation with sport.

Data analyzed were collected in the Spring semester via interviews after the implementation of both lessons. The students were interviewed one-on-one by science teacher candidates who assisted the lead author with data collection. The science teacher candidates included one Latinx female and one White male. Interviews took place in the hallway outside of the students' classroom to provide privacy in sharing responses, while not being too far-removed from their classmates and teacher. The interviews were semi-structured and lasted between 20 and 40 minutes. The interviews focused on student background and past experiences (e.g. What are you interested in doing for work or as a career in the future? How did you become interested in this career?); academic and school history (e.g. How have your experiences been so far in this science class? What do you like or do not like about science class/your science teacher? Do you feel as though you fit in or belong in this class? Why?); students' sense of belonging (e.g. When you were doing sports in science class, did it help you enjoy science class more? Why? When you were doing sports in science class, did it help you fit in better or work better with other students? Why? When you were doing sports in science class, did it help you connect with your teacher? Why? What new things did you learn about your teacher?); and future interest in STEM careers (e.g. When you were doing sports in science class, did it make you more interested in a science, math, engineering, or technology job or career for the future? Why?)

The interviews were recorded, then transcribed verbatim and analyzed thematically (Saldaña, 2015) seeking student responses relevant to the research question, namely social connectedness. Triangulation (Jensen, 2008) for trustworthiness of findings was satisfied via interviewing multiple student participants. In analyzing

Table 3.1 Interviewed High School Biology Students by race, gender and affiliation with sport

Pseudonym	Race/ethnicity	Gender	Affiliation with sport
Nikolas	Native American and White	Male	Actively engaged in sports
Oscar	Latino	Male	Actively engaged in sports
Jonah	White	Male	Actively engaged in sports
Asha	African American	Female	Not engaged in sports
Sophie	White	Female	Not engaged in sports
Liza	White	Female	Not engaged in sports

data and deriving claims, the lead author worked most closely with Mr. Tony, the lead classroom teacher. Member-checking (Jensen, 2008) was used to facilitate this process where the lead author presented questions and developing ideas to Mr. Tony and Ms. Jane who responded, clarified, specified, corrected, or expanded upon these. Insights gained from the implementation of the lessons and the study have guided ongoing revisions and subsequent lessons implemented with additional students, including increasing the clarity with which the sport model was presented and implemented and more explicit modeling in analyzing and interpreting data. These revisions are discussed towards the end of the chapter.

3.4 Findings

Student responses to interview questions revealed the following themes: (i) more enjoyable and beneficial science learning experiences for the students; and (ii) opportunities to foster social connections among the students and between the students and their teacher, Mr. Tony. Additionally, (iii) despite a lack of interest or participation in sports, specific impacts on the female student participants included that learning science in a sports context was effective for them and they were able to explain these processes in their own words. For one female African American student, this science learning experience reinforced her pre-existing motivation to pursue a nursing career.

3.4.1 More Enjoyable and Beneficial Science Learning Experiences

Some students explained that integrating sports into science made the learning process more enjoyable and successful because it connected to their out of school interests. Even for students who were not typically engaged in sports outside of school, learning science through sports was simply fun and provided opportunities to be more actively engaged in learning as opposed to passively listening to their teacher. When asked, “Have you enjoyed learning using sports? Why was that?”, Nikolas, a Native American and White male engaged in sports shared that:

> ... out of school, I like to play sports. So, learning in a way that I like, that’s enjoyable for me, helps me concentrate and enjoy because if you don’t enjoy something, you’re bored. And if you’re bored, you don’t pay attention. You don’t comprehend what is happening.... I play sports outside of school a lot.

Similarly, when responding to the same question, Oscar, a Latinx male often engaged in sports, shared that “[Playing sports to help me learn science is]... more fun. I like playing soccer.” Both young men acknowledged that they enjoy sports and participate in sports outside of school. The sports context of the science lessons aligned with these students' preexisting interests out of school. Nikolas, in his response above, went on to discuss the important correlations between interests, engagement, and learning. Additional enjoyable features of the sports units for students included the opportunity for active engagement in order to learn science. Jonah, a White male engaged in sports, explained:

> [Playing sports to help me learn science was enjoyable]... Yes.... Because you got to do something active and such. It's a lot, it makes classes a lot more fun when you get to actually get up and do something.... I'm normally that kind of person who really does sports... When I do them, I'm *into* them....

When asked in a follow-up question, "Did you look forward to coming to science class?", Jonah stated, "Yes.... I really like this class. It makes it fun...." , indicating an enhanced interest in science class.

The female participants were not engaged or interested in sports prior to these lessons. Despite this, they similarly explained that science class was more active and enjoyable and, as a result, more beneficial to their learning when taught in a sports context as opposed to a passive, teacher-centered learning environment. When asked if her teacher's instructional approach to use sports to teach science was helpful, Asha, an African American female student, explained that "It's more hands-on than just sitting there and listening.... Because you got to enjoy different things and then like you got to have fun while also doing school work." Similar to her classmates, Asha also agreed that this approach engaged her interests in class more effectively and that she believes that she was able to learn more successfully. Asha stated, "... because class is boring.... I feel like I learn better with doing sports...." Sophie, a White female, also explained that playing sports to help her learn science was enjoyable "... because it was more hands-on rather than just sitting in the class like listening to a lecture."

3.4.2 Opportunities to Foster Social Connections

In designing the basketball lesson, the teachers structured in an opportunity for students to play team basketball, which involved the students and two teachers playing against each other in teams of three. Similarly, in the soccer lesson, students had the opportunity to play against each other in teams for friendly competition. These opportunities to play in teams helped foster social connections, even among students who did not know each other well before. Students were asked, "When you were doing sports in class, did it help you fit in better or work better with other students?" They discussed how this team structure supported a more personal and friendly learning environment. Sophie explained that "... because we had to have teamwork when we were playing soccer.... I actually didn't know a large percentage of this class until we played soccer and I met them.... It was more like personal and interactive...." Nikolas similarly explained that he was better able to fit in and work with other students, "... because we were on teams. So, we had to work with our teammates." Asha also agreed that structured opportunities for teamwork in the sports context helped her fit in and work better with her classmates, despite her not previously enjoying collaborating with others: “Yes.... because I don’t like working with other people. [So, it] helped a lot. ...” Asha went further to explain that not only did she enjoy working other classmates, but she also made new friends while participating in the sports-focused science lessons: “Yes. I got to make more friends and I got to know a lot about more people in the science class.”

Beyond experiences of greater social connectedness among students, some students discussed the impact of these lessons on their relationship with their science teacher, Mr. Tony, stating that they learned more about him and cultivated a more personal relationship with him. Oscar explained “... because I was playing with my teacher and [classmates] and got to know them better. [For instance, I]... learned what sport they [my classmates] liked. Like they liked soccer. [I learned that my teacher]. .. likes soccer and he likes sports.”

Sophie also commented about her new insights about her teacher: “[I learned]... just how outgoing he is.... Yeah he really is [good at soccer]!” Jonah and Nikolas discussed how they appreciated Mr. Tony as a teacher. Jonah enthusiastically described his relationship with Mr. Tony and how Mr. Tony balances fun with seriousness in learning: “... the teacher-student buddy thing.... you’re really friends with that one teacher and next year, you’re like, “Hey.” I got that.... He [my teacher] is really fun and serious sometimes.... Like, at times he gets kind of scary-serious. It’s amazing!” Nikolas indicated that he recognized the effort that Mr. Tony put forth in designing instruction around their interests: “Yeah.... Because he actually knows what we like to do, what we all like to do and he picked it [basketball], so, because we liked to do it.”

3.4.3 Specific Impacts on Female Student Participants

None of the female students were engaged in sports nor indicated that they enjoyed sports. Despite this, they each reflected on why the process of learning the targeted scientific concepts through engagement in sports was beneficial to them, beyond enjoyment. In other words, they were able to explain how learning through sports helped them learn the content better. They were not interested in learning activities that were simply fun and active. When asked if the lessons made science class more enjoyable, Liza, a White female student, agreed, but quickly explained that the sports, in and of itself, was not what made it valuable for her. Rather, she explained how learning by being immersed in sports supported her in learning the concepts more effectively:

> It did [make science class more enjoyable]. I mean, I thought it was a good opportunity but I—I wasn’t really interested in it because you were—I don’t like basketball first of all. Basketball is just not a thing for me.... But I think it was like, it was helpful to see how things and like what you can do.... Like in the situation or in the adaptations you were given.... Because it like—one-on-one interaction. You got to go do it and see how it [the scientific phenomenon of an organism surviving or dying] works. Like, it’s not just like shown to you [by the teacher or in a textbook]—you’re doing it.

The activity of attempting baskets under variable conditions served as a concrete model for Liza to understand how organisms are variably at an advantage or disadvantage for survival. This embodied process of learning by "doing it" was a more effective way for her to learn as opposed to attempting to understand the concept by the teacher explaining or presenting it. The ways in which the female students discussed their experiences in the lessons underscores that the sports-based activities were educative and not used as fun classroom management "hooks" or gimmicks. Similar to Liza, Sophie explained why this learning experience was effective for her:

> Because if we're like playing a sport outside of school, we're not like actually with the learning aspect and we were [learning in this case].... I actually felt the muscles we were talking about [in the biomechanics unit] like working which really made a difference.

Asha was the third female participant. Similarly, despite a lack of interest and engagement in sports, in and of themselves, this means of science engagement supported her in connecting what she was learning to future science career interests that she had already established.

> ... you got to see different movements – how the body works, how the bones—like how your body moves.... It made me really want to become a nurse now.... [because, in the biomechanics unit,] you got to learn the parts in the body and how they work and how they move.

These impacts of in-class science teaching and learning aligning with Asha's science-related career interests would be important in reinforcing and sustaining these interests over time.

Overall, social gains among students as a result of learning biology embedded in the described sports and physical activities context included benefiting from a more enjoyable and engaging science learning environment, learning more about peers and their science teacher, fostering meaningful connections to their teacher and new connections to peers, reflecting on future science-related career plans, and thinking metacognitively about how the instructional unit supported them in learning the material.

3.5 Discussion

This study sought to explore the ways in which teaching biology through sports and physical activities supported social connectedness and other social gains among students who were culturally diverse, as well as variably interested and involved in sports. First, a model for teaching biology through sports and physical activities was presented to expand this pedagogical approach beyond advanced physical science and to support positive social gains among students. Furthermore, the model was implemented with a group of culturally diverse high school students who varied in terms of race, ethnicity, gender, and sport involvement. Teaching science through sports and physical activities had the effect of making the science learning experiences more enjoyable and beneficial for the students, as well as supported social gains, particularly social connectedness between the students and their peers, their teacher, and learning science. The female students also articulated the ways in which the sports activities facilitated their understanding of the targeted content. Gains for the female students interviewed were comparable to the males interviewed, as well as between the selected students who were more and less interested in sports. This was encouraging given research that indicates the potential to marginalize students in sports contexts due to these differences.

When seeking to implement more culturally inclusive pedagogy, teachers must be aware of the social, historical, and institutional contexts to which the ideas underlying instruction are connected as these can evoke both positive or negative experiences and emotions for students (Rodriguez, 2017). In regards to teaching science through sports, important concerns included the potential of biasing students who enjoyed sports and were more involved or skilled in sports (Grimminger, 2013). Similarly, there were concerns about marginalizing students based on ability or able-bodiness (Sato & Haegele, 2017), as well as biasing male students over female students based on ideologies regarding body image, skills, gender, and other social factors (Azzarito & Solmon, 2006; Brock et al., 2009; Garrett & Wrench, 2018; Nicaise et al., 2006; Nilges, 1998; Tischler & McCaughtry, 2011). Additionally, Black students, especially Black males, are challenged by prejudicial ideologies that emphasize physicality over intellectual capacity (Harper et al., 2013; Harrison & Lawrence, 2004; Sailes, 1993). Engaging in sports in order to learn can, therefore, be an empowering, prideful, and positive experience for students, but it can also potentially be risky, shameful, or dehumanizing. Additionally, one reviewer of this work raised questions regarding the appropriateness of modeling sexual reproduction via teams involving students and teachers and the potential of triggering negative emotions and experiences amongst students. Within the context of this work, the teachers and students exhibited positive connections and rapport. Additionally, the activity in which students and teachers formed teams was optional and the students led the team selection; however, many negative reactions can take place silently and beneath the surface (Mark, 2021). Thus, this guidance is taken seriously and will inform future pedagogical efforts to ensure that no students are made to feel uncomfortable. Again, a major concern when implementing this work has been awareness of social, historical, and institutional contexts.

Rodriguez (2017) advocates for teachers to be supported in developing critical emotional pedagogy and other proficiencies in order to understand the contexts within which these emotions can develop and to gain practical skills in designing instruction to cultivate a positive social experience for students. While this perspective did not inform the design of the lessons, there was some evidence of alignment to these important considerations. None of the participants in the study discussed feelings of embarrassment, negative peer perception, or any kind of ridicule or stereotyping despite being varied in terms of athletic interest and skill, as well as racial, ethnic, and gender identity. From observations of the lessons being implemented, students depicted high levels of engagement and enjoyment. There were lots of cheers and sustained attention throughout the physical activities components of the units. These lessons have remained highly popular and anticipated among subsequent students. These positive outcomes were likely due to the teachers' instructional design by which, of focus, were sports activities, as opposed to win-lose competition. In attempting baskets, students were randomly assigned traits that would aid or hinder them to a greater degree than natural skills. In other words, students were focused on the effects of the physical and behavioral traits that they modeled rather than their natural abilities to successfully score baskets. Students were never singled out or intentionally selected by teachers to perform, demonstrate, or opt-out of a physical activity. While the students themselves were not made to feel inferior, as discussed earlier, greater caution will be taken to directly address important differences between animal and human systems in the ways in which physical and behavioral limitations and survival of the fittest operate. While physical and behavioral limitations can be significantly disadvantageous and threatening to the survival of animals in the wild, humans have greater capacities to adapt, as well as are more driven to be inclusive to people of diverse abilities and characteristics. It will be important to have these conversations before and/or after modeling the systems with students.

Furthermore, the opportunity to play team basketball, which was more competition-oriented, was optional for students. Only interested students participated, thereby reducing any feelings of unease. Yet still, the process of choosing teams was connected to targeted content and, therefore, still educative. Although all students did not play, all students watched and the teachers referred back to the process of team selection during whole-class discussion following the activity to make analogous connections to sexual selection. In light of these concerns, findings indicating positive gains in social connectedness among peers and with the teacher for both male and female students and students ranging in sports interest and skill are very encouraging. These indications are especially encouraging for the female participants who explained that they were not interested in or disliked sports, but yet felt positive feelings of social connectedness to their male science teacher and their peers in the context of playing sports.

None of the female participants were engaged in sports nor indicated that they enjoyed sports; however, they articulated the ways in which learning science through sports was effective for them, beyond making class and learning more enjoyable. This finding was consistent with previous research in which, through focus groups, female science students showed that they actively reflected on instructional strategies that supported them in learning science deeply (Buck & Ehlers, 2002). Specifically, the female students expressed a desire for more hands-on and active learning, but not for fun; rather they believed that these instructional approaches would provide them with more concrete ways of understanding the content beyond reading and note-taking. They further critiqued learning experiences when they were asked to complete hands-on activities with limited explanation of how it was connected to targeted content by their teachers.

As teachers prepare to utilize sports and physical activities as instructional resources, the diverse needs and interests of all students in the classroom must be considered. As the data indicated, even students usually uninterested in sports may enjoy and benefit from learning through sports; however, for students uninterested in or resistant to learning through sports or physical activities, such lessons may not best serve as learning activities as they may become impediments to equitable learning opportunities for all students. Rather, sports-based lessons can be offered as one of several varied options, including those not involving sport and physical activity; but all targeting the same student learning goals. Student choice can then be allowed where interested students can choose to participate in the sports-based lessons. This supports differentiation in instructional design and student choice, which are both best practices in equitable teaching and learning (Brown-Jeffy & Cooper, 2011; Buck & Ehlers, 2002).

3.6 Limitations and Future Research

There are a number of limitations to consider when implementing action research (Stringer, 2008). Action research can be limited by focusing on driving questions and issues specific to particular contexts and, thus, limiting its transferability. The effectiveness of sports as a framework for science teaching may be specific to this community of students and their teachers, however, cultivating social connectedness through intentional instructional design is a broadly compelling goal to enhance the science educational experiences for groups of students in other settings. Additional limitations of action research include the personal nature of the research context in which teachers collaborate with researchers to investigate themselves and their own teaching practices. The researchers are limited, as well, in investigating the practices of individuals with whom a familiar relationship has been cultivated. While these are acknowledged limitations, the outcomes of action research are much more beneficial to the community in which the research has been conducted as the teachers have developed expert knowledge to be utilized in ongoing practice with the same or future students.

The study was also limited in terms of focusing data analysis on a few students as opposed to a larger data set, as well as interviewing students about their teacher at the time and his teaching practice; however, this approach was used to analyze open-ended, qualitative responses to support deep understanding from students' perspectives. Among a larger data set, the effectiveness of this pedagogical approach for students is expected to vary; however, determining successful strategies for some students, even if not all, is still an advancement as the approach of teaching science within sports contexts adds to the collective set of strategies available for educators. Informed by this study focused on sports as a framework, social connectedness may be targeted by utilization of other frames, including arts-integration, social justice, and global citizenship, as examples.

Additionally, if, instead of interviewing students, data analysis focused on the teachers' perspectives only or effectiveness defined in terms of students' academic gains on content-based assessments, then this would fail to capture necessary insights of the students' social experiences during learning. Future research would aim to gain understanding of impact from larger numbers of students. Additionally, the purpose of the study was to investigate social impacts. As stated earlier, student gains in targeted knowledge and skills solely or primarily as a result of the sports-focused lessons, distinct from more traditional instruction, was not investigated and will be in future efforts.

3.7 Data-Informed Development of the Biology Lessons Over Time

The original purpose of these lessons, specifically those that integrated basketball, was two-fold. The first was to create engagement in science through movement and physical activity. The second was to model a concept of change over time that the team of high school biology teachers believed would be difficult for their students to understand and explain as some aspects of natural selection and adaptation are not readily discerned from a reading. There were some initial limitations, namely some instances of lack of clarity and connections to the targeted concepts, as well as students' limited analysis of data. Despite these limitations, the design and implementation of basketball game play as an instructional model served to aid students in explaining the phenomenon of Darwin's theory of natural selection in a relevant and time-condensed manner and did advance learning goals among this group of students, even if more modest in the first iteration. Through basketball game play, students benefited from first hand experience of a process reflective of survival based on the fitness of specific traits, thereby providing them intimate knowledge of a process of change and adaptation that takes hundreds of years to develop.

The first year this lesson was implemented, many challenges in comprehending the content standard and the scientific practice of arguing from evidence were still present among students; however, there was the strong, immediate connection between students and teachers, as well as among students. This social connectedness supported an important cultural shift in the classroom community as the students now saw their teachers as, not only experts in teaching, but as social, interesting, and invested partners in their learning. From assessment data not included as part of this study, there was an increase in students' test scores in this newly implemented unit centered on sports and physical activity compared to prior forms of instruction, but this increase was not as large as the teachers anticipated.

Subsequently, a number of changes were implemented hoping to improve upon the model driven, in particular, by an emphasis on high yield practices of teacher clarity and student-teacher relationships (Hattie & Zierer, 2017). Changes included the teachers modeling the activities for students prior to the students implementing the activities themselves and more clearly explaining the conceptual ideas underlying natural selection. The teachers also displayed and utilized the data in more effective ways. Specifically, in the first iteration, data were collected and displayed nearby to each basketball game play station, but during subsequent iterations, the teachers more intentionally focused students' attention back to the data displayed and more continually emphasized and modeled the analysis and interpretation of these graphical data. Students reflected on the data and made interpretations in writing in order to derive reasons for variation of traits, competition, advantages of species possessing certain traits, and to explain why species that possess certain traits were more likely to survive and reproduce. The data also illustrated the counterintuitive randomness of selection by the fact that 'advantageous' traits did not always help organisms succeed. From school-based assessment data, not included in this study, these changes led to increases in student mastery (as defined by state assessment standards) of the scientific practice of analysis and interpretation of data in both formative assessments and state-level testing. Even more, for each successive iteration of the lesson, according to the teacher team, there was growth beyond the previous year for students in regards to this measure of proficiency for this scientific practice based on both the teachers' formative assessments and state-level accountability measures (State Department of Education Assessment Data, n.d.). No validity measures were conducted against the teacher team's claims, however. This is a recognized limitation and will be conducted in future investigations.

Other improvements in the lesson included that students who were willing to challenge other students or teachers in the team competition aspect of the lessons were later asked to complete a separate reflection that focused on the reasoning underlying their choices of teammates and the result of the team challenges. This written reflection was far more specific than previous years where the team competition aspects were debriefed only verbally in a whole-group setting. The students' written reflections on this aspect of learning provided resources that added to the verbal, whole-class discussion, which helped support greater student understanding of natural selection versus sexual selection. Additionally, an alternative assignment was provided as an option for those students who did not want to participate, or could not, in the physical activities. This assignment required students to make detailed observations and record data for the student-centered sport model being implemented, as well as for other species going through natural selection and sexual selection.

The most consequential outcome of the lessons was that both students who participated in the lessons directly, as well as those who only indirectly heard about it from other students, regarded the learning experiences as successful such that future classes began asking if this was a lesson *they* would get to participate in and when it would occur. Success from these students' perspectives, in addition to the interview data provided, meant that the learning experiences were engaging, productive for their learning about scientific concepts and phenomena, and, importantly, socially connected. These classes became a social and cultural context in which students wanted to participate and looked to with anticipation.

3.8 Conclusions

This research was supported by University of Louisville, College of Education and Human Development Research and Faculty Development grant funding. The goal of this internal grant was to support pre-tenure faculty at the institution in conducting smaller-scale pilot research to bolster future efforts towards acquiring larger, external grant funding. The main barrier to disseminating this work centered on efforts to publish. The researchers acknowledge that earlier drafts of the manuscript were in need of revision and substantial revisions have been completed; however, all but one of these decisions did not invite resubmission. Oftentimes, criticisms of the work centered on the lack of attention to measurable gains in students' academic achievement and cognitive processing as a direct result of these lessons. The challenges here were at least two-fold. First, the study sought to examine social connectedness as a necessary factor in supporting academic gains. Second, the educational and social contexts of the students' academic performances included many challenges that might not be necessarily overcome with the implementation of these lessons alone; however, significant enhancements to the students' learning environments might have been achieved as a result of these lessons, namely greater interest and social connectedness regarding science education and career development, that might also persist well beyond the study.

What is being argued in this chapter is an important focus on the quality of students' learning environments, including students' emotions and social contexts, even if students do not make statistically significant gains in content-focused post-assessments. While dismissing the pedagogical efforts discussed in this study as insufficient to be effective in elevating this group of students' academic performances, some of these critiques also dismissed the role of significant educational and social inequities in interpreting the academic performances of the students. For students who have historically experienced school science as uninteresting and alienating, gains in social connectedness, as a potential precursor for long-term academic and career interests in science, are argued as significant and attributable to this team of teachers and their pedagogical efforts in developing and implementing the sports-focused biology lessons.

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Chapter 4
Science Teachers' Views on the Integration of Science and Language for Emergent Bilinguals in Grade Sixth Classrooms

Sissy S. Wong, Jie Zhang, Araceli Enriquez-Andrade, and Ma. Glenda L. Wui

4.1 Introduction

Emergent Bilinguals (EBs), students who are learning a language other than their home language, face double challenges in learning content while developing English language skills in science classrooms. Adolescent emergent bilinguals are often placed in simplified science courses and have less access to advanced science courses (Thompson, 2015). To increase these students' access to challenging science, researchers have proposed that integration of science teaching with English language acquisition to help EBs simultaneously learn content and language in the classroom (Lee et al., 2019; Stoddart et al., 2002). In this scenario, the teachers' role is essential for the design and implementation of language-rich and inquiry-based science instruction that provides authentic and meaningful opportunities for students to read, write, talk, and engage in evidence-based argumentation to justify claims (Osborne, 2010). The issue is that these opportunities will not be incorporated in science classrooms unless the teachers view these activities as effective, meaningful, and practical (Hutner & Markman, 2016; Richardson, 1996).

This study stems from a larger project named Dialogic Inquiry for Socioscientific and Conceptual Understanding in School Science (DISCUSS). The purpose of DISCUSS was the development of a curriculum that integrated meaningful opportunities for English language acquisition while learning concepts regarding space science. Our research team comprising of two faculty, a postdoctoral researcher, and

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doctoral students in the areas of science education, bilingual education, and social studies, partnered with three sixth-grade science teachers and a science specialist in a local urban school district with an average of 40% EBs. The research team developed a four-week unit on a Socioscientific Issue (SSI) – Space Exploration during the summer term. After meeting with the school team for feedback, the topic of space exploration was chosen because it is geographically relevant to students in Houston and aligns with the district's sixth-grade science curriculum pacing guide which provides timelines for covering the content standards during the academic year. The unit addressed a central contestable question: Should the U.S. government increase funding for space exploration?

This qualitative study had two purposes. First, we explored middle school science teachers' views about science and language integration and emergent bilinguals to understand how views impacted teacher choices and practices. Although the DISCUSS project did not intend to examine teacher views as an intervention outcome, we fully recognize that views play a critical role in teacher decision-making and are of great interest to this research work. Views are defined as, "ontological, epistemological, and ethical commitments" (Mathews, 2009, p. 642). Examining teachers' views are important because they consist of sets of beliefs regarding a topic, such as phenomena, interests, or field of study (Dagher & BouJaoude, 1997). For example, scientific views consist of various sets of beliefs about science, such as the origins of science, scientific phenomena, scientific activities, and processes, as well as the limits of science and scientific knowledge. Since beliefs about teaching and learning can influence the choices teachers make in the classroom (Bryan, 2012; Hunter & Markman, 2016), understanding teachers' views provides an avenue to explore teacher choices. In addition, how a teacher views students influences what they think students are capable of and impacts their expectations of students (Cummins, 2000).

The second purpose of this study was to document and reflect on successes and challenges resulting from the development and implementation of a literacy-infused SSI-based curriculum in sixth-grade classrooms with predominantly emergent bilinguals. Drawing on previous literature on teacher resistance to pedagogical and ideological changes (Rodriguez & Kitchen, 2005), we unpacked institutional, ideological, and epistemological barriers for teachers to fully implement the integrated DISCUSS curriculum.

In this chapter, we first reviewed the literature on socioscientific issues and science education, teachers' views about science and literacy integration, and emergent bilinguals. We then describe the methodology used in this study and identified themes that emerged from the data about teacher views, followed by discussions about the implications for teacher preparation and teacher professional development for working with emergent bilinguals. Finally, we reflected on the challenges in developing and implementing language-inclusive science curriculum and pursuing external funding to continue this work.

4.2 Theoretical Framework

In this chapter, we view our work through the Culturally Relevant Pedagogy (CRP) framework. Ladson-Billings identified the need for a culturally relevant theoretical perspective that addressed the growing disparity between the racial, ethnic, and cultural characteristics of teachers and students (1995a). To address this, she coined culturally relevant pedagogy (Ladson-Billings, 1995b) to describe "a pedagogy that empowers students intellectually, socially, emotionally, and politically by using cultural references to impart knowledge, skills, and attitudes" (Ladson-Billings, 1994, p. 18). Gay (2010) described culturally relevant teaching (CRT) as "using the cultural knowledge, prior experiences, frames of references, and performance styles of ethnically diverse students to make learning encounters more relevant to and effective for them" (p. 31). Gay's CRT adapted Ladson-Billings' CRP further extended its definition by explaining that CRT is a combination of multiple pedagogies using students' cultures in the learning process. Although Ladson-Billings focused on describing the knowledge and practices of effective teachers of African American students, Gay (2013) emphasized modifying curriculum by including students' background to maximize learning by linguistically, racially, and ethnically diverse students that were not being served well through traditional schooling. Over time, Gay's CRP evolved to focusing on teaching with curriculum only as a component instead of the main component. CRP is especially important in science teaching because students in non-dominant groups often find school science curricula, instructional practices, and school science culture to be rigid, predetermined, and exclusionary of their values and experiences (Barton & Yang, 2000; Shanahan & Nieswandt, 2011). To promote science interest and engagement, science teachers should draw on culturally relevant science teaching to make the science they are teaching accessible and relevant. In our study, we used a curriculum for professional development that not only used a relevant issue as context for scientific inquiry, but also included lessons that made this relevant issue more accessible to EBs by using language and literacy strategies in inquiry-based science lessons.

4.3 Socioscientific Issues (SSI) in Science Education

Teachers must situate science learning within real-world problems because it helps to represent the field of science in authentic ways and promote scientific literacy to participate in critical social discourse (Sadler, 2004). One way to provide real-world scenarios for science teaching is to embed Socioscientific Issues (SSI) in the science curriculum. SSIs are contentious social issues with procedural and conceptual links to science (Sadler, 2004). Research has shown the promise of SSI-based lessons to enhance students' scientific reasoning, argumentation, decision making, and science content learning (Sadler et al., 2017; See review in Sadler, 2011). It is also well documented that collaborative argumentative discourse benefits science learning and students' understanding of concepts is enhanced when they are taught to reason, argue, and think critically (Osborne, 2010). However, most previous work on inquiry-based SSI instruction focuses on monolingual students for older adolescents, and rarely addresses the linguistic and cultural needs and resources of multilingual learners to successfully engage in SSI lessons (Osborne, 2010).

Despite the potential of SSI instruction to expand emergent bilingual students' linguistic and science practices, to our knowledge so far, there are no published studies on how literacy integrated SSI-based instruction may affect early adolescent EBs' science learning and English language development. There are no studies that address teachers' views of the value and challenges of literacy and SSI integration for EBs. Previous research suggests that teachers generally perceive the values of SSI in enhancing motivation and meaningful science learning (Sadler & Dawson, 2012), but there are several challenges to designing and implementing inquiry-based SSI lessons. Firstly, materials for SSI-based instruction are scarce (Sadler & Dawson, 2012). Secondly, implementing an SSI-based curriculum requires a flexible interdisciplinary approach, yet cross-curricular cooperation is lacking in many schools (Sadler & Dawson, 2012). Thirdly, teachers feel pressure to address state mandated science content standards and may feel they have limited time for teaching about social and ethical issues (Sadler, 2011). Lastly, and perhaps most importantly, teachers find it difficult to move out of the role of conveying accepted scientific knowledge to the role of the moderator of student dialogue (Osborne et al., 2002).

To address these challenges and create teacher buy-in, the research team in this project met with school leaders and science teachers to discuss SSI that best aligned with sixth grade Texas Essential Knowledge and Skills (TEKS), which are Texas's state content standards. Socioscientific issues were chosen based on four criteria: (a) relevance and interest to students; (b) science content behind the issue; (c) accessible ethical tensions; and (d) alignment with Texas state science curriculum standards. The research team met with the science teachers to co-develop the curriculum over the summer and conducted a full-day Professional Development (PD) workshop before the start of the intervention. During the PD, teachers were provided with a series of language and literacy instructional strategies to support EB students' participation in classroom discourse and science sense-making. The language and literacy instructional strategies included effective vocabulary instruction, reading comprehension strategies using thinking aloud and graphic organizers, small group collaborative discussions, and quick write of Claim, Evidence and Reasoning (CER) strategies. The authors sought to understand teachers' views about SSI lessons, and how language and literacy can be supported through SSI lessons for emergent bilinguals. Examining teachers' views about science and literacy integration can help inform educators about areas of need for curriculum development and teacher professional development to enhance science and English language learning for emergent bilinguals.

4.4 Teachers' Views About Literacy Integration in Science

For decades now, researchers have explored teachers' views of science and literacy integration (Lee & Buxton, 2013; Stoddart et al., 2002) and their impact on emergent bilingual student learning through teacher PD or interventions (Bravo & Cervetti, 2014; Maerten-Rivera et al., 2016; Waldrip, 2011). Stoddart et al. (2002) developed a science–language integration rubric based on study findings from interviews of elementary science teachers who participated in a science–language integration project. The complexity in science–language integration was represented on a "continuum of understanding that moves from a restricted view in which boundaries between domains are viewed as impermeable to an elaborated, differentiated perspective that acknowledges a reciprocal and synergistic relationship between domains" (Stoddart et al., 2002, p. 674). In other words, science-language integration ranged from science and language as distinct and separate concepts to science and language being intertwined and collaborative. Waldrip (2011) reported that elementary teachers who focused on science without strong integration with literacy tended to produce teaching that lacked contextual relevance, while teachers with more inclusive integration helped their students achieve deeper levels of understanding. The issue is that, in the United States, science and English language arts (ELA) are typically taught separately, and as independent content areas, specially at the start of middle school. Because of these disciplinary settings, science teachers often focus primarily on the development and understanding of scientific concepts with English literacy development as a secondary focus (Stoddart et al., 2002). Science teachers also find challenges when they move from viewing science and language as distinct areas for instruction to views of an integrated approach to science and language instruction (Stoddart et al., 2002). Teachers' views about the importance of language and literacy instruction in science classrooms influence their perceptions, judgment, and pedagogical choices, which impact student engagement, interest, behavior, and achievement (Mantero & McVicker, 2006; Pettit, 2011; Richardson, 1996; Rueda & Garcia, 1996). Therefore, it is important to understand teachers' views to learn how their views may influence everyday classroom choices particularly in multilingual settings.

The DISCUSS project is built on the premise that integrating Socioscientific Issues (SSI) with inquiry-based science instruction and language literacy strategies promote science and language learning for emergent bilinguals because relevant and authentic SSI provide a contextualized setting for extended dialogue, language-rich scientific inquiry, deeper understanding of science concepts, and academic language use to address complex and socially relevant science problems (Dolan et al., 2009). The ultimate goal of this instructional approach is to prepare scientifically literate citizens who both participate in ethical and well-informed decisions about critical societal issues.

The authors of this study aimed to understand the factors that impacted how and why teachers used or did not use the integrated DISCUSS curriculum. Throughout the project, we realized that the curriculum was not being fully implemented as designed by the research team. We noticed that one major issue was our initial lack of understanding regarding the impact of the participating teachers' views about science and literacy integration. Teacher views influence how they prioritize and situate learning, as well as the curricular choices they make when teaching. Therefore, for this study, we examined two middle school teachers' views about language-science integration for emergent bilinguals from the lens of Stoddart et al.'s (2002) continuum.

4.5 Teachers' Views About Emergent Bilingual Students

Just as teachers' views about the integration of science and English language development, as well as SSIs, influence choices in the classroom, teacher views about EBs hold important implications for instruction and expectations in the classroom. Teachers' views about emergent bilinguals may be exacerbated by teachers' prevailing monoglossic language ideologies—emphasis on clarity, appropriateness, and formality of language—an approach valuing the standardization of the English language (Lemmi et al., 2019). To better serve EB students, educators need to adopt culturally relevant pedagogy that resists and changes cultural and linguistic bias against EB students (Rodriguez & Kitchen, 2005). For example, instead of focusing on pronunciation and spelling of vocabulary terms, teachers could integrate culturally relevant examples of weathering and erosion by having students explore examples in their neighborhoods, or the impact of weather and erosion on important culturally relevant landmarks.

However, teachers generally report a lack of self-efficacy in teaching EBs. In fact, only 15% of teachers feel adequately prepared to work with EBs (Banilower et al., 2013; NASEM, 2018). Research work has shown that teachers with limited knowledge of multiculturalism and multilingualism, and instructional strategies appropriate for EBs have contributed to the achievement gap between EBs and monolingual learners (Lucas & Villegas, 2011; Murphy & Torff, 2019). Teachers with limited understanding of EBs' linguistic backgrounds, culture, and ethnicity tend to hold deficit views of students as a homogeneous group with language deficiency and assume EBs are unable or unwilling to communicate with their teachers or monolingual peers (Stephens, 2019). This, in turn, can influence teachers' instructional practices that may result in EBs' academic failure (Gilakjani & Sabouri, 2017; Lucas et al., 2015).

4.6 Methods

This study is part of DISCUSS, a larger project designed to integrate inquiry-based science and SSI-based curriculum for sixth-grade middle school science classrooms with predominantly EBs in Texas. The larger project involved three teachers that implemented the DISCUSS curriculum, as well as two control classroom teachers that taught the science content according to the school's curriculum pacing guide. Lessons were videotaped and multiple student and teacher outcomes were measured before and after the intervention, which are reported in separate research publications. This study employed a qualitative comparative case study approach (Creswell, 2014) to examine two teacher's views about science and literacy integration and teaching EBs after participating in the DISCUSS PD and intervention. This pilot study was funded by a university-awarded grant to the second author for a total of $20,000.

4.7 Settings and Participants

The study took place in an intermediate school in urban areas in southeastern Texas. About 80% of the students in the school were economically disadvantaged or eligible for free or reduced-price lunch (Texas Education Agency 2017–2018). For the current study, 53% of the student participants were non-native English speakers. Of these, Spanish was the primary language. Ethnicity included 48% Hispanics, 30% African Americans, 10% Asians, 2% European Americans, and 10% others or multi-ethnicity. Among non-native English speakers, most (68%) were born in the U.S. and foreign-born students made up 32%. Although Texas state curriculum standards maintain that use of students' primary languages is allowed during content-area instruction (TEA, 2020), inexplicit micro/school culture typically prevents teachers from using students' home languages in science classrooms (Langman, 2014).

For this study, we explored the views of the two middle grades teachers who implemented the DISCUSS curriculum. The participating teachers, Ms. Humphrey and Ms. Ortega (pseudonyms), were recommended for the project by the science lead person in the school. The research team met with Ms. Humphrey and Ms. Ortega and discussed the overall objectives of the DISCUSS curriculum. The teachers were also informed they would receive small financial incentives for input on curriculum development and implementation, as well as all curriculum materials including a set of stomp rocket kits for the rocketry lessons.

Ms. Humphrey is an African American teacher with 8 years of experience, who taught the general education science class that included a mix of ethnicities and language groups. She has taught speech and debate, financial education, social studies, and science in the United States. She has been teaching sixth-grade science to Gifted and Talented students for the past 2 years. Her original degree was in counseling. Early in her counseling career, she was asked by a school administrator to become certified in social studies and was eventually moved to a teaching position in social studies, and then certified and instructed sixth-grade science.

Ms. Ortega had 34 years of teaching experience working with special education and EBs. She is from Puerto Rico and identifies as Hispanic. Ms. Ortega speaks fluently in both languages, Spanish and English. She taught the bilingual science class at the school where the study took place, and all her students were Spanish speakers. She began her career as a bilingual teacher and has taught upper elementary science, social studies, and mathematics in Puerto Rico and the United States. She holds a bachelor's degree with a major in Special Education and a minor in Socially Disadvantaged and Autistic Children, and a Master's in Counseling.

After agreeing to participate, the research team regularly reached out to both Ms. Humphrey and Ms. Ortega for feedback on the development of the DISCUSS curriculum. We intended to co-develop the curriculum with the teachers, but given the busy summer schedule, we were only able to schedule two meetings during the summer to go over the drafts and seek feedback. The teachers were given small stipends to attend the meetings, and both attended the two sessions. Before the start of the year, the teachers received a 5-hour training on the DISCUSS curriculum and embedded science and literacy strategies, as well as developing students' English literacy skills, before its implementation. The professional development (PD) lasted for one day because it was before the start of the school year, and the teachers had limited time to meet with the research team.

Of note, the study was scheduled to occur after the first week of school's start. Unfortunately, Houston and surrounding areas experienced a major natural disaster during late August. Hurricane Harvey displaced many families from their homes; thus, the start of the school year was delayed by 3 weeks, and the intervention study was postponed to early October instead of being implemented in early September.

4.8 Researcher Perspectives

Although the research team created the curriculum, the researchers were considered participants for this study. The research team for this project comprises faculty, postdoc, and graduate students in science education, bilingual education, and social studies education. The first author of this book chapter is a Chinese, female faculty member in science education, and became fluent in the English language as an emergent bilingual when she entered kindergarten after immigrating to the United States as a child. The second author is a Chinese, female faculty member in bilingual education. She is a native Mandarin speaker and learned English as a second language. The third co-author is a doctoral student in science education and an elementary classroom science teacher. She is bilingual in both Spanish and English. The last author was a doctoral student in social education and is now a faculty member in the Philippines. She was instrumental in the DISCUSS curriculum design and implementation and is bilingual in both Filipino and English.

Our team takes an asset-based perspective of EBs' multicompetences (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018). That is, EBs' linguistic and cultural resources are important to incorporate in science instruction as they provide rich and meaningful opportunities for diverse ideas and multiple perspectives in thinking about science (Lee & Fradd, 1998; NASEM, 2018). This point of view provides ways to enrich instruction, elevate proficiencies in science learning, and offers alternative modes of exploration that deviate from more traditional approaches. EBs are competent learners who contribute, collaborate, and thrive in settings that foster simultaneously development of proficiencies in science knowledge and multiple languages. The research team has been actively working with pre-service and in-service science teachers to integrate linguistically, socially, and culturally responsive strategies in science instruction through revising pre-service teacher coursework, teacher professional development, and field research with local school districts. The team values and supports bilingualism and English language development in authentic science classroom contexts.

4.9 DISCUSS Curriculum

The DISCUSS curriculum featured a 7E (Elicit, Engage, Establish, Explore, Explain, Elaborate and Evaluate) instructional model (August et al., 2014), and targeted the development of EBs' background knowledge (Elicit) and vocabulary of the lesson (Establish). We did this to design lesson following the CRP framework that addresses the growing language disparities between EBs and their non-EB peers. The initial lessons included a newsletter that introduced real-world issues related to Space Exploration, elicited students' prior knowledge, and prompted for initial thoughts on the central question. During the four-week curriculum implementation, students engaged in inquiry-based activities and read argumentative texts that were designed for EBs. The texts and all student materials were carefully crafted to provide learning support for EBs. For example, clear headings were used to highlight each side of the argument; key science content-specific vocabulary (e.g., *emissions, degradation*) and general academic vocabulary (e.g., *insulate, resilience*) were defined for teachers to access; in addition, relevant background information and visual representations (e.g., graphs and pictures) were provided to facilitate text comprehension. Furthermore, all students participated in small-group discussions throughout the 4 weeks, including topics regarding the impact of space exploration on technological innovation, earth and space environment, economy, and public policy.

Throughout the curriculum, there were prompts for the formation of student groups and for these groups to discuss their ideas, write claims, and evidence and reasoning (CER) statements while engaging in inquiry-based and hands-on activities designed to promote scientific discourse. Throughout the unit, students collected evidence as they engaged in the inquiry activities and reading, and considered both sides of the curriculum central question, which is whether the government should increase and why it should decrease funding for space exploration. The researchers attempted to prepare the participating teachers to use a series of scaffolding moves to facilitate small group Collaborative Reasoning discussions (Clark et al., 2003). The scaffolding moves include prompting for position and reasons, modeling and thinking out loud, asking for clarification, challenging, reminding, encouraging, fostering independence, summing up and re-focusing, and debriefing.

During the latter part of the intervention, students engaged in additional discussions about the central question and wrote individual decision responses stating their opinions on whether to increase or decrease funding for space exploration. The students' writing was supported through the collaborative work on argument diagrams outlining claims, evidence, and reasoning (CER) elements, weekly quick write, and peer feedback. A more detailed description of the DISCUSS curriculum is provided in Zhang et al., 2018.

4.10 Data Collection and Analyses

The primary data sources for this study were two interviews (Stake, 1995): A post-intervention interview, or Interview 1, conducted by the researchers to investigate the teachers' educational background, views of language, science, and integration of both. The teachers were also asked about the use of SSI, and the DISCUSS curriculum. Another post-intervention interview, or Interview 2, was conducted by the researchers one year after the intervention to gain understanding regarding the teachers' views on integrating science and literacy, teaching EBs, and the impact of participating in the study. Each interview lasted about 30–45 minutes in person. The interviews were transcribed verbatim for analysis. Additional data sources included classroom observations (at least twice a week in each classroom), field notes, informal conversations, and videotaped lessons.

We used a qualitative approach to identify and examine codes within the interview data. Thematic analysis (Braun & Clarke, 2006) was used to identify the themes from the four interview transcripts. The identified themes were triangulated from other data sources such as field notes, classroom observations, and informal conversations (Creswell, 2014). In the next section, we present themes that emerged from the data.

4.11 Findings

We share the identified themes from the multiple data sources described above concerning the teachers' views on the integration of science and literacy and EB students. Our analyses revealed four themes: teachers' conflicting views about science and language integration reflect two institutional barriers: constraints due to time and district pacing guide, and English-only school language policy; teachers hold varied views on their preparedness for working with EBs; teachers view their role and responsibility to integrate language and science differently; teachers' views about the EB students.

4.11.1 Theme 1: Institutional Barriers Prevented the Integration of Language and Literacy Within Science Instruction

An emergent theme from collected data revealed that two institutional barriers prevented teachers from effectively integrating science instruction and targeted English language acquisition strategies. These barriers included the district's time-restrictive curriculum pacing guide for science instruction, and the district's language policy. Both teachers agreed on the importance of inquiry-based hands-on instruction in science, but they shared that student-centered practices, such as inquiry-based hands-on learning, were constrained by the time-restrictive district's curriculum pacing guide. While Ms. Humphrey held student-centered views regarding science learning by emphasizing student exploration of concepts, further in the interview she revealed that exploratory activities do not occur often because of the time limitations inherent in the district's curriculum pacing guide. When asked about the parts of the DISCUSS curriculum she liked, Ms. Humphrey shared that "The essence of [hands-on activities are] great. I just think that the time [to conduct them] wasn't there" (Interview 1).

Like Ms. Humphrey, Ms. Ortega's viewed hands-on science activities with opportunities for reading as important components for student learning. However, she prioritized keeping up with the curriculum pacing guide over providing opportunities for students to engage in time demanding inquiry-based activities. When asked if she implements any activities or strategies from the DISCUSS curriculum, Ms. Ortega stated that:

> We are in a situation where they [administration] want science to be very hands-on, but the time given, which is 45 minutes at the maximum, does not permit [to do both] hands-on learning and reading instruction at the same time. So, reading activities cannot be as extensive or detailed as much as I would want it to be. (Interview 2)

Both teachers expressed concerns about the language-rich science activities described by the DISCUSS curriculum. They were concerned that the pacing of DISCUSS curriculum literacy activities were not well aligned with the district's curriculum pacing guide. For example, the DISCUSS curriculum unit on space science was expected to be taught in 4 weeks, however the district's pacing guide only allotted 3 days for space science instruction. Even though the teachers understood that the district supported the project, they viewed the pacing guide as more important due to the pressure to teach a pre-determined amount of science content in preparation for benchmarks and state assessments. The teachers stated that the DISCUSS lessons contained too many concepts and reading texts, and required dedicated time for discussions, reading and writing opportunities. As such, and the teachers felt pressured to teach the curriculum quickly.

Based on our observations, the teachers did not often follow the lessons as planned or skipped major parts of the lessons that focused on language integration. The teachers' behaviors supported Osborne et al.'s (2002) finding that teachers feel pressure to teach content and often exclude social and ethical issues, such as SSIs. Osborne et al. (2002) also argued that teachers often view their role as conveyors of knowledge and not as moderators of dialogue. This, coupled with time constraints, may have resulted in Ms. Humphrey and Ms. Ortega's explanations for wanting to implement inquiry-based science investigations activities, but rarely did so because of time constraints. In the end, both Ms. Humphrey and Ms. Ortega prioritized their views on following the district timeline over the extended time permitted by the district for this study and what research supports as effective practices to support EBs' learning of content and language.

The second barrier is the teacher's interpretation of school language policy. Ms. Ortega viewed the student's home language, Spanish, as an important tool to build science understanding for her Spanish-speaking students. When asked if she felt her ability to speak Spanish is beneficial in her teaching, Ms. Ortega shared that:

> I think it's important for a child that is new [to the U.S.] to hear a language that is their mother language, you know, that they don't have to struggle with everything. At least I can provide a secure environment for them to learn, and I let them learn. Like sometimes the new ones [students], they have so much to say, but they cannot express it. And then there are some [instances] where I just say I want you to express yourself in Spanish first, ok? (Interview 2)

Ms. Ortega viewed the use of Spanish was an important tool for science learning but was concerned about not following the school's language policy. She viewed it as her responsibility to comply with the district's monolingual policy, so her views on Spanish use and the language policy were in direct conflict with one another. When asked in what ways does she view using Spanish in the classroom as affecting students' understanding and learning about science, she shared that:

> So, all I could do is tell them that I'm not allowed to read this in Spanish, but if you want, I can give you a dictionary [to learn new words in English], and I will read it for you. And that is what I offer to the lower beginner students. So, depending on what level they are as bilinguals, I can maybe do some accommodations. (Interview 2)

Ms. Ortega seemed unresolved as to how and when to use Spanish and tried to use Spanish to mediate meaningful opportunities and occurrences to teach science and language. After an incident that involved a meeting with an administrator and that included criticism of using too much Spanish in her teaching, Ms. Ortega prioritized her views on the monolingual policy and minimized and discouraged the use of Spanish in science learning. In continuing to share her views on using Spanish in the classroom, and how it affects students' understanding and learning about science, she stated:

> They'll tell me, I think I can do it in Spanish. I'll tell them, let's do it in Spanish. Now, can you translate that? I don't have a problem with children translating words. But yes, there is a moment where too much Spanish in the classroom, it is too much. And I'll tell them, nobody is allowed to translate right now, you need to get the information directly from the teacher or directly from the reading, no translations. Let's see what you can pick up. And you'll see them flustered — did you get it? And then I asked them to just tell me what they picked up from listening or reading and what they did not, and we'll go from there. But yes, there are moments, as the year goes on, I'll say, I don't want to hear anybody translate. No

> peer group now. Nothing, you need to focus on, understanding what I said in English, nothing else. (Interview 2)

Ms. Ortega's views that following the district's monolingual policy superseded her beliefs that Spanish could be an important tool to help her EBs negotiate science and language learning in her classroom. As the only teacher in this study that taught in a bilingual science classroom, Ms. Ortega viewed that teaching only in English may not have been effective for her EBs because of the students' various levels of English proficiency. Her views regarding the importance of using Spanish to help students access the content conflicted with the school's emphasis of English instruction and accountability mandates. To mediate this dissonance, Ms. Ortega utilized Spanish to facilitate learning vocabulary or simple concepts and found it necessary to scaffold the removal of Spanish supports over time.

It should be noted that the DISCUSS project did not stipulate on Spanish use and encourage teachers to follow the district's recommended practices. The project provided an opportunity for us to study teachers' language ideology and observe teachers' spontaneous use of Spanish in a bilingual science classroom. In another paper (Enriquez-Andrade et al., 2019), we have systematically transcribed and analyzed Ms. Ortega's Spanish talk during the four-week DISCUSS intervention period and the findings showed inconsistencies between the teacher practices and beliefs regarding Spanish use and literacy integration. Although recognizing the importance of Spanish use for science understanding for EBs, she used Spanish talk mainly to draw connections between Spanish and English vocabulary (e.g., el telegrama vs. the telegram) or for nonacademic purposes like redirecting behavior and reiterating instructions previously given in English. These findings are consistent with the literature that although teachers believe that the use of home language benefits student learning, they are constrained to enact such views because of English-only instructional policies in schools (Razfar, 2012). At the same time, the prevailing science standards that require educators to expect and use standard academic English as the 'proper' form of written and spoken communication within the science classrooms disregards the diversity of students' culture and linguistic backgrounds (Gutiérrez & Rogoff, 2003; National Research Council, 2012; Razfar, 2012).

4.11.2 Theme 2: Teachers Were Not Prepared to Teach EBs and Need Support to Develop Asset-Based Views

Another theme that emerged from the data was the difference in teacher's views regarding their level of preparedness to work with EBs in science, and suggested need of teacher support to combat deficit thinking. Ms. Ortega stated that she did not feel adequately prepared to draw on students' linguistic assets, even though she is a native Spanish speaker. When asked if she felt prepared to teach English language learners when she first started teaching in the United States, she shared that:

> When I came to Unites States, I was not, I felt that I wasn't as prepared. I guess just because of the pacing guide, what was asked, it was a new group, I mean, I handled third, fourth and fifth before, you know. I had been a special ed. teacher. So yeah, there were a lot of things going on. (Interview 2)

It was surprising to find that Ms. Ortega viewed herself as unprepared to teach EBs. This is especially interesting because Ms. Ortega is bilingual herself, and studies have shown teachers who know a second language tend to understand the challenges of learning content and language simultaneously (Pettit, 2011). This is also surprising because Ms. Ortega has spent a part of her career as a bilingual teacher. This may be because of the unique bilingual science class setting where all the Spanish speakers in her classroom were beginners and newcomers. During the interviews, she repetitively expressed the challenges in working with newcomers in her science classroom.

On the other hand, Ms. Humphrey viewed herself as being well-prepared to work with EBs. She stated she was prepared and knew to use the same strategies in her classes for EBs and non-EBs, because language and literacy strategies benefited all students. Although Ms. Humphrey felt that she was prepared, her views that EBs do not require differentiated instruction indicated a limited understanding of how to work with EBs. When asked if she felt prepared to teach EBs when she first started teaching, she shared that:

> I found it very easy [to teach English to EBs]. In a lot of cases, students [native English speakers] are behind in grade level so I'm really teaching everybody English. When you are talking about fluency, a lot of our kids are not fluent…I find it easier to train all of that at once. (Interview 2)

Ms. Humphrey's views that all students, include EBs, do not need differentiated instruction was emphasized again. When asked if there is any kind of professional development that she wished she had on working with EBs, she stated that:

> I know that most of my kids benefit from English language learning strategies. I think the mistake that many people make is thinking that English language learning is just strictly for English language learners. But really, most of the kids these days are underdeveloped in their academic discourse skills and their literacy fluency. So, unless they are in private school, a lot of kids need it [English language skills]. I find it very easy, and like after nine years, like I said, I know that this is the case with a lot of our students. They need the extra support for building up their vocabulary and their literacy skills. (Interview 2)

Additionally, Ms. Humphrey viewed herself as prepared for working with EBs because of her own experience living abroad in a non-English speaking country. She believed that her experience of being immersed in a non-English speaking country elevated her level of preparedness and knowledge on how language should be integrated into the classroom (See Suriel & Atwater, 2012). When asked who she thought is primarily responsible for teaching English to EBs, Ms. Humphrey shared:

> I am also a culturally immersed person. I went to another country for a whole month and that's just kind of works. I mean, if you're immersed into a new culture and its language, you're going to pick it up a lot faster, so I think that it's important. I mean those two things aren't exclusive — like part of being immersed into the culture when you go into the educational arena you would get that as well. (Interview 2)

Even though both teachers held differing views of preparedness to teach EBs, and their roles in integrating language in science, both seemingly held basic views about how to integrate science and language. Both teachers emphasized teaching vocabulary as the means to include language instruction in science teaching, which represents a simplified and basic understanding of integration (Stoddart et al., 2002) and did not include or discuss additional pedagogies or strategies to integrate English language learning with science. The two teachers did not fully recognize the importance of various language-rich discussion strategies from the DISCUSS curriculum. When asked how she integrates language into science teaching, Ms. Ortega stated, "I integrate science and literacy by teaching vocabulary, vocabulary is the key" (Interview 1).

Ms. Humphrey, who shared that she viewed herself as prepared and knowledgeable about integrating science and language, also emphasized the importance of focusing on vocabulary instruction as her main way of integrating language learning in science instruction. When asked how she integrates language learning in science teaching, she shared:

> Vocabulary foldables are important. [One can use] a vocabulary word, its definition and a picture and with the help of a peer, one can figure out which pictures best supports the definition. Vocabulary foldables, peer talk, annotations, things like that writing, speaking, presentations, things like that [are helpful to learning language]. (Interview 2)

Ms. Humphrey seemed to hold high self-efficacy working with EBs and felt that she did not need additional training to work with EBs but could benefit from targeted opportunities to develop an understanding of effective instructional strategies for EBs. This prompted our research team to wonder whether her high self-efficacy beliefs may hinder her professional growth with integrating English language learning and result in perpetuating learning gaps between EBs and non-EBs (i.e., Lucas & Villegas, 2011; Murphy & Torff, 2019). In addition, our project indicates that teachers did not leverage their students' linguistic assets for science teaching and learning, as we sought to promote, and instead held on to their low expectations. As mentioned earlier, deficit-based teaching views focus on what students need or lack. In contrast, asset-based views of EBs involves the appreciation of their linguistic and cultural diversity, as well as using these attributes to inform lesson planning, instruction, and assessment. Unfortunately, our study was too short, and it did not have enough funding to provide on-going professional development. This speaks to the need to support responsive and sustained professional development especially targeted for helping teachers identify, reflect upon, and change deficit views of multiculturalism and multilingualism.

4.11.3 Theme 3: Teachers Vary in Their View of Responsibility for Integrating Language in Science Classrooms

Each participating teacher in this study held differing views regarding whose role it was to integrate English language instruction in science instruction, but agree they have a role in integrating lessons with both sets of knowledge. Ms. Humphrey shared the view that she has a role in integrating language in the science classroom, while Ms. Ortega viewed that the responsibility of integrating language in science resided with the district specialists since they design the district's curriculum pacing guide. Ms. Humphrey viewed language integration as her responsibility. Although Ms. Humphrey based her understanding of integration on personal experiences (Caswell et al., 2016), she viewed herself responsible for integrating English language learning with her science teaching. When asked who is primarily responsible for teaching English to EBs, she stated:

> I do think that the teacher should integrate English language learning within the course they are teaching, however, it's a village activity. English is learned from day to day experiences. You don't just learn it in the classroom, but it's an important factor. When you're immersed into any culture, you're going to learn its language [and modes of expression] from different things, you know. But it should also be a priority to all teachers [to integrate English language learning]. (Interview 2)

On the other hand, Ms. Ortega stated it was not her role to integrate science and language, and the integration of English language learning within content areas should be prioritized by the school personnel that designs the district's curriculum pacing guide. When asked about who is primarily responsible for teaching English to EBs, she shared that "It is not the teacher that you have to talk to, it is actually the district specialist who make the pacing guide and they will have to incorporate something like that" (Interview 2).

Ms. Ortega also believed that integrating English language learning in science was not solely her responsibility but required collaboration with a bilingual teacher. When asked again during Interview 2 about her views on integrating language and science, she stated:

> When it comes to science, it is most important to develop the concept. I think that any language should be enough to develop the concept. Later if they [students] understand the concept, then the teacher can translate into the English. This is one theory for integrating English language learning and science content. (Interview 2)

Ms. Ortega's views support findings that middle school science teachers do not view it as their responsibility to teach language and science (Stoddart et al., 2002). This is of concern given the literature that views that silo language learning from content instruction impacts teacher judgment and instruction, which in turn, impacts student behavior, interest, engagement, and achievement (Mantero & McVicker, 2006; Pettit, 2011; Rueda & Garcia, 1996). It must have also been frustrating for Ms. Ortega to have been hired as a bilingual teacher, yet not have the preparation nor support from the district to teach EBs.

4.11.4 Theme 4: Low Expectations Prevented Asset-Based Instruction with Emergent Bilinguals

The last theme from this study regarded the teachers' low expectations about their EBs as ***students*** in their science classrooms. Views about students are critical as they frame thinking about their capacity to learn and expectations of learning. Teachers that hold more asset-based views embrace higher expectations from their students. During the interview, Ms. Humphrey stated that her students are divergent thinkers with great minds, and her goal was to foster this creative and divergent thinking. These statements seemed promising and showed that she held asset-based views of her EBs. However, one concern is that the class we observed also contained gifted and talented students. It was possible that her statements referred to this particular student population as divergent thinkers, however, the researchers did not prompt further. In the end, she seemed to veer towards low expectations when she stated that EBs were hesitant to participate in class, are often "far behind", and needed more time to learn. When asked whether she felt she was prepared to teach EBs when she first started teaching, she stated:

> I find it easier to, umm, to train all of them at once. Which is a little bit helpful. I mean it's unfortunate you know that they're so far behind academically as far as having academic discourse, but I find that all of them can use help with English language learning strategies – these strategies help a lot of my students, so I don't find it difficult. (Interview 2)

Ms. Ortega saw her EBs and newcomers from other countries as "clueless" and that they "bring very little to the table." Although Ms. Ortega recognized that EBs require additional time to process information in two languages, she viewed EBs as having limited prior knowledge in science and English and viewed her EBs students as unable to engage in appropriate and content-based discussions. When asked what she thought about the integration of socioscientific issues in the DISCUSS curriculum, she shared:

> I would have loved to sit down in a regular classroom to see if the children had more background knowledge on issues like that. Because what I noticed in this classroom [of mostly EBs] is that the students bring very little to the table you know. For example, when I try to flip the classroom, which means that I try to give them something to take home so that they can analyze it and bring it back for discussion, that part is not there yet. We are not there yet. With other groups, I can do that. (Interview 1)

Ms. Ortega may not have realized that there could have been other reasons that students were not ready for discussions. For example, students' limited English abilities likely prevented them from understanding assignments well, or there is no one at home fluent in English to help them with assignments. Again, these findings point to the need to fund more responsive and sustained professional development on culturally responsive teaching and multilingualism. Teachers' strongly held views, like those of Ms. Ortega, cannot change overnight, and sustained professional development could assist teachers better understand their own biases, as well as potential systemic inequalities that hinder EBs' learning.

Ms. Ortega also viewed EBs as students that lack prior knowledge. This is revealed when she was asked about the impact of the district's monolingual policy, she stated:

> We do have to understand that some of our bilingual children are coming in without any science [knowledge], so they are not bringing in any conceptual understanding. So, I have different levels of [understanding among the] children. I may have a child that has no or minimum exposure to science concepts, and that child may also not know any English. (Interview 2)

In addition, her lack of knowledge of, and support in, teaching EBs was disappointing because, based on our classroom observations, she spent most of the instructional time teaching vocabulary. She often switched to Spanish for non-science aspects of instruction, such as classroom management, but rarely used Spanish for teaching content. This instructional decision may be due to her views of English vocabulary as a prerequisite of science learning, a commonly held view by science teachers (Lee et al., 2019; Meier et al., 2020). Her views and practices presented as challenges to teaching diverse students, but this was compounded by the school's existing monolingual policy. The combination of her views, practices, and the existing monolingual policy hindered her ability to teach in her students' home language which she stated was an important avenue for reaching her EB students. Having Ms. Ortega facing teaching in the context of these challenges is especially troubling since she was the only bilingual teacher included in our study and had the highest percentages of EBs in her classroom.

Ms. Ortega's ability to teach EBs was also impacted by her low expectations of them because it prevented her from using her knowledge and skills as a bilingual teacher to help her EBs. For example, she could have used code switching and cognates to negotiate the learning of English and content over time if the monolingual policy did not prevent this. This supports the need for bilingual CRP educators to understand the challenges posed by institutional policies such as the one on use of the English language only. These views serve as ideological barriers to her teaching for diversity (varied English proficiency) and understanding (science inquiry, student-centered learning) in a bilingual science classroom (Rodriguez & Kitchen, 2005). The findings of this theme support Stephens's (2019) finding that teacher with limited understanding of EBs' linguistic backgrounds, culture, and ethnicity tend to hold deficit views of students as a homogeneous group with language deficiency and assume EBs are unable or unwilling to communicate with their teachers or monolingual peers.

We acknowledge that there are distinctions in the real inequalities and realities of teaching EBs, and teachers' actual deficit views. Although these are different ideas, these ideas may be reciprocal as the real inequalities, and the resulting decreased engagement in science and lower academic achievements, reinforce the low expectations teachers' held. Our project was not designed to address views, but we realize views played a large role in how the curriculum was interpreted and implemented. It is necessary, when implementing work that addresses teacher knowledge and practice, to include views as a target construct.

4.12 Discussion

This study contributes to the literature by examining the integration of science and literacy through the implementation of an SSI-based science curriculum that includes English language and literacy learning strategies in sixth-grade classrooms with predominantly emergent bilinguals. There is a need to address the growing disparities between EBs and their native English speaking peers by providing relevant, meaningful, and sustained professional development and teacher supports that address systemic inequalities and teachers' low expectations. Four themes are identified from the interview data. Firstly, evidence from two emergent themes indicated several institutional barriers for the teachers to fully implement the DISCUSS curriculum (e.g., limited time, district pacing guides, English-only policy). Secondly, the data revealed that one teacher felt unprepared to teach EBs, and the other teacher felt prepared, but this may not be so. Thirdly, the teachers varied in their views about whose responsibility it is to integrate English language learning and science instruction but focused on teaching vocabulary as a means to integrating language in science. Lastly, teachers' strongly held views of their EBs were impacted by their low expectations and the school's monolingual policy. This in turn influenced the teachers' pedagogical choices (Walker et al., 2004). Furthermore, teachers with compartmentalized views of academic disciplines and language or literacy, combined with low expectations for EBs hinder their ability to construct academic environments that are conducive for science-language integration (Stoddart et al., 2002).

4.13 Limitations of the Study

This study has several limitations. First, both teachers were provided the curriculum in advance to review before each meeting, but it seemed that neither prepared for each of the two meetings because the teachers exhibited limited understandings about the curriculum and provided minimal feedback. Over 3 months, the limited feedback provided by the teachers did not result in constructive revisions, so although we wanted to co-design the curriculum, the curriculum was designed by the research team without significant teacher feedback.

Another limitation of the study was that the intervention originally scheduled to take place in early fall was postponed to late fall due to Hurricane Harvey, a natural disaster that flooded many areas in the Houston metropolitan area. The disaster resulted in school districts delaying the start of school by approximately 3 weeks. The second author of the chapter was a victim of Hurricane Harvey. We were grateful that the pilot study was carried out later than planned, but the timing was not ideal and all stakeholders including teachers, students, and researchers were heavily impacted by this unprecedented natural disaster.

4.14 Implications and Future Directions

Despite the mentioned limitations, the current study has important implications for language-inclusive and equity-focused STEM research, policies, and practices to address disparities in opportunities to learn. First, the findings call for teachers' preparation programs and professional development to provide more direct and purposeful opportunities for teachers to elicit, examine, and reflect upon their ideological and pedagogical orientations about the linguistic and cultural diversity of emergent bilinguals and science-language integration. Teaching for diversity should be made a priority in teacher preparation and professional development to fully implement the integration of science and language for EBs (i.e., Buxton et al., 2015; Caswell et al., 2016; Shaw et al., 2014); change teachers' views about diversity and equity; and address the pervasive resistance to pedagogical change and resistance to ideological change in science (Rodriguez, 2015). In addition, PD should include educating teachers about students from different countries, particularly from low SES, that might not have had consistent schooling and science instruction previously. Targeted PD on CRP and multilingualism may have helped teachers, like Ms. Ortega, to gain a better understanding of these students and effective practices to use in her classroom.

To promote teaching for diversity and understanding, deliberate opportunities to elicit, discuss, and reflect upon views through authentic dialogical conversations can result in a positive change in teacher views and beliefs (Rodriguez & Kitchen, 2005; Walker et al., 2004). From the bilingual education perspective, it is critical to shift teachers' language ideology from treating language as a problem to language as a resource to right (Ruiz, 2010), and from exclusive language ideology (valuing standardization of English) to inclusive language ideology (valuing multiple forms of language or multiple language uses) (Lemmi et al., 2019). For teachers, school leaders, district administrators, and other educational stakeholders to support and advocate for socially, culturally, and linguistically responsive science learning opportunities for EBs, it is critical that all stakeholders engage in these conversations for systemic change to occur.

Second, creative, and transformational fieldwork in STEM education requires a long-term, mutualistic, and trusting research-practice partnership (RPP) (Penuel & Gallagher, 2017) with teachers, school principals, and district science leaders. Educators and school partners should respectfully negotiate and mutually agree upon common problems of practice and policy parameters that may serve as institutional barriers to fully implement innovations. To facilitate teacher learning, allow teacher ownership of curriculum, and increase flexibility to adapt lessons, a research team may consider developing educative curriculum materials (Davis & Krajcik, 2005), instead of providing prescribed lesson plans and supporting materials.

Third, much funding support is needed to engage all stakeholders in this important yet challenging work. With more appropriate funding, teachers can be provided a better incentive to participate in curriculum co-design; more systematic and coherent teacher support can be developed including intensive teacher PD, ongoing coaching, and feedback necessary to integrate language strategies in science. Teachers can also be provided with release time to observe other teachers, which can help the teachers shift to more assets-based views. Moving forward, research work will need to focus on more time and ongoing support to help teachers, school leaders, and educators appreciate and embrace a more asset-based and inclusive view and belief system.

4.15 Challenges and Perseverance in Seeking Funding

The research team has been pursuing federal and foundation grants to continue this work. The top challenge we have encountered so far is that we are constantly asked by the reviewers to address the alignment of our theoretical framework and project design with NGSS. We are working in a non-NGSS state, and it is difficult to balance the content-focused State Standards in Texas and NGSS while developing curriculum and building research-practice partnerships. Secondly, funding agencies seem to be more interested in supporting quantitative research on teacher- and/or student-related outcomes, but we argue that qualitative methods, such as case studies and critical ethnographies, are needed to unpack the complex dynamic nature of the interactions between teacher language ideology, science and language practices, and school language policies before scaling up the innovations in STEM education.

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Chapter 5
Teacher Candidates and the Equitable, Inclusive Science Classroom

Joi D. Merritt and Angela W. Webb

5.1 The Complexities of Preparing Teacher Candidates to Teach Science in Our Context

As classroom populations become more diverse, the teaching population has continued to be predominately White (Taie & Goldring, 2020). This is reflected in our own teacher preparation programs, which are even more overwhelmingly White and female (over 80%). As science teacher educators, we thought about the fact that science is often presented as "objective". However, science is not an objective field as it dismisses other ways of knowing and understanding the world around us because it is often seen through a White, Western lens (Bang et al., 2013). In addition, disparities in academic outcomes for Black, Latinx and Indigenous students persist between these students and other groups (Howard, 2019). Simultaneously, we, the authors, feel charged with preparing teacher candidates (TCs) to teach science equitably in the inclusive science classroom to meet the needs of all students with the nation's increasingly diverse student body (Taie & Goldring, 2020). Thus, we decided that it was imperative to revamp our science methods courses to more explicitly address the issues of equity, diversity, social justice and racism. Each of our courses touched upon these issues, but we wanted to make changes to our elementary and secondary science methods courses such that we would intentionally support students in thinking more deeply about how to address issues of equity, diversity and social justice in all aspects of their teaching of science.

As we examined different aspects that impact our TCs, we also recognized we must embody and reflect relevant dispositions, beliefs, and practices in our own teaching to better prepare TCs to teach equitably. By embodying these dispositions,

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beliefs and practices ourselves, we can serve as exemplars for the inclusive, equitable science classroom as we also support TCs in learning and understanding how to do this in their own classrooms. We focused on diversity, equity and social justice as important to all aspects of our science teaching practice. Our definitions of diversity and equity are similar to those defined by Rodriguez and Morrison (2019). We define diversity as acknowledging the differences (e.g., disability, age, gender, race, LGBTQ2+) that exist among students and that TCs should view these differences as a resource and strength to their equitable, inclusive classroom community. We define equity as being fair regardless of these differences by allocating resources and mitigating discrimination so that all students are able to have success. Social justice in science education is defined as "using science knowledge and skills to make the world a fairer and more just place for everyone" (Greenberg, 2017, p. 70).

In this chapter, we detail our journey in revamping the elementary and secondary science methods courses in preparing TCs to work with students from diverse backgrounds. We begin by discussing our specific context for science teacher preparation. Further, we discuss Critical Race Theory and culturally relevant pedagogy that frame our work and how these led to changes in the elementary and secondary science methods courses. We then discuss how we used action research to conduct our study and analyzed our data through the lens of CRT. Next, we discuss whether and how TCs' perspectives changed during our courses by answering the questions: How do TCs express value in diversity and equity in the science classroom? How do they embrace those learning opportunities? Finally, we discuss the impact of these changes on each of us as teacher-scholars and the implications of this work for teaching science methods courses.

To revamp the courses, we utilized Critical Race Theory (CRT; Crenshaw et al., 1995; Ladson-Billings & Tate, 1995) as it provides the opportunity to examine whether and how the structures and aspects of the science methods courses address race, racism, equity and social justice. We used the following central questions to revamp the science methods courses: Which voices are we privileging in the readings that TCs consume? Have TCs had the opportunity to grapple with and reflect on whether the diverse students they teach are empowered in their learning of science through the phenomena, activities and readings that the TCs' students are engaging with during learning? Are TCs provided opportunities to identify and leverage the strengths their students bring through their communities, families, stories, knowledge, language and experiences into their teaching of science?

5.1.1 Context of Teacher Candidate Preparation

As TCs complete their education courses at our university, they also participate in their field-based teaching practicum (discussed later) in local city and county school districts. Many of our field-based placements appear to lack diversity (racial, linguistic, gender identity, etc.). The field placements at the elementary level often include other support specialists beyond the cooperating teacher. Elementary field placement classrooms often include reading specialists who pull out the students who need additional support in developing literacy skills. In addition, they often have support specialists for multilingual learners (González-Howard & Suárez, 2021) and students with disabilities. As a result, when issues of differentiated instruction are discussed in the elementary methods course, TCs will often talk about how their cooperating teachers said that it is unnecessary for them to address it because they have the support specialists to support student learning. In the secondary practicum field placements, when the importance of differentiated instruction is acknowledged, it rarely extends beyond elements of student choice of assignments. Therefore, in our context many cooperating teachers in the field placement classrooms are not addressing issues related to racism, supporting students of varying abilities, multilingual learners, etc., then we cannot expect TCs to be aware of, observe and apply how to support the learning of all students who are a part of their classroom community.

Field placements in some school districts for our TCs has meant that they experience classrooms and neighborhoods that are not welcoming to diversity as ideals and beliefs that are freely expressed. For example, it is not unusual to drive to field placements where confederate flags decorate lawns or for students to wear clothing displaying the confederate flag, "a symbol of racial hatred" for Black people in the United States (Orey, 2004, p. 4). In these schools, it has been observed and reported by TCs and university supervisors that teachers with students of color in the classroom do not correct White students from calling students of color, colored people, a historically offensive statement to African Americans/Black people. Thus, TCs can be successful in their practicum placements and future teaching positions without paying attention to these barriers because some local teachers do not attend to issues of equity, diversity and social justice. Accepting this status quo is counter to our commitments as socially just science teacher educators and would be a disservice to our TCs who will now be held accountable for "demonstrat[ing] a commitment to equity and provid[ing] instruction and classroom strategies that result in culturally inclusive and responsive learning environments and academic achievement for all students" (Virginia Department of Education, 2021, p. 8).

We, the authors, also faced changes in the science content standards of learning in the Commonwealth of Virginia. In 2018, new science content standards of learning were adopted that reflected aspects of the Next Generation Science Standards (NGSS). The NGSS were developed for K-12 schools and integrate three dimensions of science introduced in *A Framework for K-12 Science Education* (National Research Council, 2012). These three dimensions include science and engineering practices, disciplinary core ideas (i.e., physical sciences, life sciences, earth and space sciences) and cross-cutting concepts. Virginia did not fully adopt the NGSS standards. Rather, the science and engineering practices were incorporated into the state's science content standards. At the elementary level, science content standards now provide a theme—a big idea that shapes what is to be taught at each grade level. In the new 2018 Virginia science content standards, middle and high school science classes, with the exception of sixth grade, remain discipline focused (e.g., life science, physical science, biology, chemistry, environmental science). Although the revision of the content standards are an improvement on previous standards, this also means that TCs continue to not experience the type of teaching that is phenomena-based and three-dimensional, or that reflect the research-based dimensions of the Framework for K-12 Science Education or NGSS. Therefore, as we drew on CRT to make changes to our courses, we also needed to ensure TCs had the opportunity to learn and understand three-dimensional science teaching, with a focus on the science and engineering practices.

5.1.2 Funding This Work

We have not attempted to secure internal or external funding nor have we sought to publish this methods course-based study. Most funding agencies prefer science education research that is aligned with the NGSS as it is a common and accepted practice in the science education community. We do not think that this study would receive external funding because Virginia is not an NGSS state and because the use of Critical Race Theory (CRT) as a framework has become a political talking point. For example, in the United States, the political right has used CRT as an argument against teaching that acknowledges the legacy of White supremacy and racism that undergirds U.S. history (Kelley, 2021). Several states have passed legislation banning the use of CRT in public schools and universities (e.g., Kelley, 2021). There is also push back from journal reviewers and editors that this work belongs in journals focused on specific ethnic groups. For example, one of the authors submitted an article to a top-tier science education journal focused on multilingual learners in which reviews commented that the article belonged in a journal focused on multilingual learners. The feedback comments from reviewers and the editor indicate that they may not recognize the connection or importance of equity, diversity and social justice in the science classroom.

Though funding agencies now have more visible calls for work focused on racial equity and student learning, they remain highly competitive and often ask for alignment with the NGSS. In addition, these calls often favor traditional, quantitative research as opposed to action research or self-study. For these reasons, we do not think it will be easy to have the study results published in a top-tiered journal or to be externally funded.

In the next section, we discuss Critical Race Theory, culturally responsive and culturally relevant pedagogy and how these frame our work and led to changes in the elementary and secondary science methods courses.

5.2 Framing the Work: Critical Race Theory

To understand the role that race plays in our course designs, we chose the lens of Critical Race Theory (CRT). CRT in educational research was first theorized by Ladson-Billings and Tate (1995). CRT seeks to "illuminate racial power and subsequent racial hierarchies, analyze their effects, understand why and how they persist, and advance social action to disrupt and alter them" (Parsons et al., 2011, p. 953). Utilizing this framework provided us the opportunity to examine numerous forms of oppression that systematically affect People of Color (Ladson-Billings, 2009). We, the chapter authors, consider People of Color as an umbrella term for all persons who are *not* White people. CRT also provides us the opportunity to identify, analyze, and transform structural and cultural aspects of society that sustain oppression, and in each of our respective classes (elementary and secondary science methods), our course design and classroom communities, that maintain the marginal position and subordination of People of Color (Crenshaw et al., 1995). Moreover, CRT acknowledges that racism occurs in various dimensions (Solórzano & Villalpando, 1998) and intersects with other forms of oppression (Crenshaw, 1993). Finally, CRT serves as a framework for our work because it privileges the first-hand knowledge of individuals (Delgado, 1995).

From this lens, TCs should be made aware of the normative practices and identities promoted in their science classrooms and consider who is included and who is excluded by those practices and identities (Cobb et al., 2009). We wanted to revamp our courses, such that TCs can reflect on the characteristics of culturally responsive teachers described by Villegas and Lucas (2002). Culturally responsive teachers:

> (a) are socioculturally conscious, (b) have affirming views of students from diverse backgrounds, (c) see themselves as responsible for and capable of bringing about change to make schools more equitable, (d) understand how learners construct knowledge and are capable of promoting knowledge construction, (e) know about the lives of their students, and (f) design instruction that builds on what their students already know while stretching them beyond the familiar (p. 20).

Thus, through CRT, we examined how to make improvements to the elementary and secondary science methods courses. Through these changes, we hope to make TCs aware of and develop the characteristics of a culturally responsive teacher.

5.2.1 Culturally Relevant Pedagogy

Ladson-Billings (1994/2009) developed culturally relevant pedagogy (CRP) as an approach that affirms and empowers students from the non-dominant class in their own learning as a means for challenging the status quo. CRP includes three tenets: academic achievement, cultural competence and sociopolitical consciousness. A CRP teacher cultivates high academic achievement, supports students in being active citizens, connects students' lives to the content they are learning and allows students to engage in critiquing cultural norms and the status quo (Ladson-Billings & Tate, 1995). TCs in our methods courses should also be developing the ability to engage in CRP.

Per the Virginia Department of Education, TCs are required to complete a diversity course as part of the sequence of courses for licensure. Although course syllabi indicate culturally relevant pedagogy is addressed in the diversity course, instructors do have academic freedom in teaching the course. As other studies have found (Kitchen, 2005; Mensah, 2009), Joi (the first author) found that when teaching, if TCs are presented with concepts they have previously learned in the diversity course, TCs pushed back either verbally, "We learned this in our diversity course" or in course evaluations in which TCs expressed similar sentiments of why the same concepts are being addressed again in science methods. Thus, we decided to take a different approach of engaging in the tenets of culturally relevant pedagogy: academic achievement, cultural competence and sociopolitical consciousness, (Ladson-Billings, 1994/2009) within the course curriculum.

5.3 Research Context and Methods

5.3.1 The Revamped Methods Courses

We start this section by describing how we revamped the curriculum using our guiding questions framed from CRT in our 16-week (semester-long) elementary and secondary science methods courses to better engage students with equity, diversity and social justice. In the prior elementary science methods course, the focus was on TCs learning how to develop lesson plans, with 1 week on what an inclusive science classroom should include, 1 week on supporting multilingual learners, 1 week on supporting students with disabilities—resulting in 2 weeks for discussing differentiated instruction. Similarly, in the prior secondary science methods courses, the focus was on TCs learning how to develop inquiry-focused lesson plans that incorporated tenets of the nature of science; a week per topic was spent reading about and discussing inclusive science instruction, supporting multilingual learners, and differentiating instruction to meet students' needs.

As we revamped these two courses, we identified *Ambitious Science Teaching* by Windschitl et al. (2018) as the textbook to use in our respective science methods courses, as it centers on equity and the science and engineering practices delineated by the NGSS and Virginia's science content standards. Adopting a common textbook for these courses would also allow us to learn from and build on one another's practices as well as examine whether there were commonalities across elementary and secondary TCs' changes in perspective during instruction. Although the textbook fits our needs to address the science and engineering practices, it does not fully encompass how we want to address equity, diversity and social justice in our courses. Whereas equity is woven throughout ambitious science teaching, the text does not specifically center students' funds of knowledge, establish and nurture inclusive classroom community, or how to connect science to local places and contexts. Moreover, issues of social justice, racism and White supremacy are not addressed in the text.

Thus, we decided to add supplemental readings focused on equity, diversity, racism, social justice, and White Supremacy in science and science education. We also looked at revamping our courses as an opportunity to include more Black, Indigenous and People of Color (BIPOC) authors. These readings range from practitioner journals (e.g., *Science and Children*, *The Science Teacher*) to using STEM Teaching Tools and Learning in Places resources (see stemteachingtools.org and learninginplaces.org briefs). These readings serve as a source for rich in-class discussions and applications in science teaching. For example, in both courses, students read STEM Teaching Tools Brief 53: "How to avoid possible pitfalls associated with culturally responsive instruction." In the elementary course, students had a frank discussion about culturally relevant teaching, equity and what the recommendations for action mean for them to actually support all students in their future classroom. In the secondary course, the class watched a video of and drew on Rodriguez's critique of Engineering is Elementary (EiE) "culturally relevant" examples in discussions of culturally relevant teaching and common pitfalls (The National Academies, 2017).

In our revamped science methods courses, TCs also engaged in activities that model how to make the science content culturally and socially relevant. For example, in the elementary methods course, students critique a science lesson plan for why it is inaccessible to all students and what specific changes they would make to the lesson. Another discussion includes classroom setup and where students are seated. Students are asked the following questions: How does the classroom setup reflect power structures in the classroom? In instruction, what are they observing in terms of discussion and classroom management? Which voices are being privileged? Which voices are being silenced? What changes can they make to develop a classroom community that values all students? Providing TCs the opportunity to think through and discuss specific aspects of their science teaching practice.

In the secondary course, TCs engage with language learner simulation videos of two lessons on circuits in French (see Webb et al., 2014; Webb & Barrera, 2017)—the first lesson highlighted a stereotypical science class without attention to the language demands of instruction and assessment; the second lesson included supports for multilingual learners (see Lee & Buxton, 2013). TCs are able to engage in a scenario in which they experience what it is like to be a multilingual learner in science, and discuss how the lesson could have been made more accessible for them as learners (see Webb et al., 2014; Webb & Barrera, 2017). TCs are also engaged in student-driven explorations focused on issues of diversity, equity, and inclusion. For example, they are given the prompt: *"As you further explore your chosen issue in groups, consider the following: Representation, Useful strategies or approaches. Post the resources you find here."* TCs are then provided links to some websites to start searching, such as Relating Research to Practice, STEM Teaching Tools, Learning for Justice, Indigenous Education Tools, and "Gifted AND Science" Google Search. In both methods courses (elementary and secondary), we implemented activities that invited TCs to think about how to make science teaching and learning equitable and accessible to all students, giving TCs the opportunity to engage in culturally relevant pedagogy in low-stakes ways that privilege multiple voices and supported sense-making.

A limitation to this work is that we are unable to observe TCs' instruction in their field placement classrooms. University supervisors, which can include faculty, observe TCs in the practicum placements associated with their methods courses as well as in their student teaching. The year of this study, neither of us served as university supervisors.

5.3.2 Context and Participants

In the 2019 fall semester, TCs minored in education and earned their state teaching license through completing a fifth-year Master of Arts in Teaching (MAT) program. For the elementary education program, TCs complete three different science content courses designed specifically for teachers (i.e., life and environmental science, physical science, and earth and planetary science) as part of an interdisciplinary liberal studies major. TCs in the secondary education program complete courses in the specific undergraduate content-area major (i.e., biology, chemistry, earth science, or physics), along with coursework in a secondary education minor. Concurrent with the science methods courses that served as the context for this research, TCs also completed a practicum. In the elementary education program, TCs engage in a one-day-per-week practicum for 13–14 weeks, including an immersion week in which they are in the practicum classroom all day Monday through Thursday and half day on Friday. In the secondary education program, TCs complete 120 hours in their practicum classrooms over the course of 8–10 weeks.

5.3.3 Research Methods

Given the iterative nature of observing, reflecting, and acting in which we engaged while and since revamping our respective science methods courses, this study best follows an action research methodology (Efron & Ravid, 2013; Holly et al., 2005). As we collaborated to better center equity and social justice in science teaching within our methods courses, we were left to consider the ways in which TCs' thinking about these issues might change over the course of the semester. We asked ourselves: How do TCs express value in diversity and equity in the science classroom and how do they embrace those learning opportunities?

To answer these questions, we examined two key course artifacts: (1) Draw a Science Teacher Test (DASTT; Thomas et al., 2001) images and descriptions from the beginning and end of the semester, and (2) science teaching philosophy statements from the beginning and end of the semester. Twenty-five elementary TCs (24 females, 1 male; 92% White, 4% Black, 4% Latinx) and five secondary science TCs (2 females, 3 males; 100% White) participated in this study in fall 2019 during their respective science methods courses. Joi (first author) taught the elementary science methods course and Angela (second author) taught the high school science methods course. We met occasionally throughout the semester to discuss common assignments and big ideas from our respective courses and to align efforts related to equity, diversity and social justice.

5.3.4 Teacher-Scholars' Positionality

Given the role of intersectionality in equity work and the situated, involved, and personal nature of action research (Efron & Ravid, 2013; Holly et al., 2005), we would be remiss to discount our unique positionalities. These are described below:

5.3.4.1 Joi

I am a Black, female, born and raised in the city of Detroit from a middle-class family. I attended what is now the Detroit Public Schools Community District public schools, which is a "large city" district according to the National Center for Education Statistics (NCES) and is a predominantly Black school district (n.d.). I earned my undergraduate degree in engineering from a predominantly White institution in a more diverse midsize city in Michigan, where I faced many instances of microaggressions as I was often the only or one of a small number of Students of Color in my classes. I became a management consultant, where I was one of two Black consultants in my home office and often worked at job sites where I was again the only or a part of a small number of consultants of Color. I then became a high school chemistry and physics teacher at a predominantly White high school in the diverse, large city Charlotte-Mecklenburg Schools. However, I taught mostly "regular" and "advanced" level classes. "Regular" level science courses tended to have the highest number of Students of Color, which meant the classes I taught tended to have a higher concentration of Students of Color. I was one of three Black teachers in our department. During department and content planning meetings, I often spoke out against deficit perspectives spoken about Students of Color. I then returned to my alma mater in Michigan for graduate school, where I again was one of a few Students of Color. Though my experiences have prepared me to work in predominantly White spaces, where students can be placed in local districts is drastically different from my own experiences. As a scholar of color, my research, teaching (including elementary science methods), and service continue to be informed by my collective experiences (social, cultural, historical, economic and educational) in each of these spaces.

5.3.4.2 Angela

I am a White female, born and raised in the piedmont of North Carolina in a solidly middle-class family. I attended private school through the fifth grade, before attending and graduating from the public Alamance-Burlington School System. Much like the schools surrounding the university that serve as the sites for practicum and student teaching placements for our TCs, the Alamance-Burlington School System is classified as “rural-fringe” by the NCES and is majority White (n.d.). I earned my bachelor’s degree in biology, secondary education from a primarily White institution located in the Blue Ridge Mountains of North Carolina. The school districts in which I completed various practicums were also rural and predominantly White (NCES, n.d.). I student taught and became a high school biology, physical science, and Advanced Placement Environmental Science teacher in Guilford County Schools, a large city school system about 20 miles from where I grew up in North Carolina. As a school district, Guilford County Schools was more diverse than schools I attended or worked in during teacher education practicum placements (NCES, n.d.), and the specific school where I taught had a fairly even demographic split between Black and White students. Teaching courses that ranged from on-level to Advanced Placement, I saw how students were stratified across courses along racial lines. I also heard the deficit-based perspectives that White teachers would take toward Students of Color in collaborative planning meetings. Wanting to challenge this accepted status quo and better serve my students, I enrolled in a Master of Education program in curriculum and instruction at a nearby university. Immediately after earning my master’s degree, I started the doctoral program in educational studies at the same university. Now as a White teacher-scholar at an institution demographically similar to the one I attended for undergraduate education in a geographic area somewhat like where I grew up, my scholarship, teaching (including secondary science methods), and service are informed by my different lenses and the ways in which those lenses have changed over time and with experience. One of my goals is to support the TCs with whom I work to be more equity- and justice-minded when they enter the classroom than I first was.

5.3.5 Data Collection and Analysis

Again, the unique characteristics of action research—constructivist, situational, practical, systematic, and cyclical (Efron & Ravid, 2013, p. 7)—are well suited for our exploration of how TCs express value in diversity and equity in the science classroom. Specifically, this action research study focuses on representations and changes in two key course artifacts—the Draw a Science Teacher Tests (Thomas et al., 2001) and science teaching philosophy statements—to address the question: How do TCs express value in diversity and equity in the science classroom and how do they embrace those learning opportunities?

5.3.5.1 Draw a Science Teacher Test

On the Draw a Science Teacher Test (DASTT; Thomas et al., 2001), TCs were asked to "draw a picture of yourself as a science teacher at work" and describe what the teacher and students were doing below the picture (p. 308). We asked TCs to draw themselves as science teachers at the beginning and the end of their semester-long science methods course. To start the process of analyzing TCs' drawings, we scored each drawing with the DASTT checklist (Thomas et al., 2001) independently, and then discussed and negotiated the scores. On the DASTT checklist, total scores could range from 0 to 13, with lower scores indicating a more student-centered teaching style and higher scores indicating more teacher-centered styles (Thomas et al., 2001). Additionally, starting with the premises of CRT, CRP, and ambitious science teaching, we used deductive coding (Yi, 2018) to re-examine TCs' drawings and to code the descriptions that accompanied their drawings.

5.3.5.2 Science Teaching Philosophy Statements

The general prompts for TC's science teaching philosophy statement were: "*Based on your own experiences, define your science teaching philosophy. In other words, how would you describe what encompasses good science teaching? What personal and professional characteristics are important for good science teaching? How do you know students have learned? What opportunities do students have to learn in different ways? How do you ensure that ALL students have the opportunity to learn?*" In our initial analysis, we used inductive coding to identify, examine, classify, and categorize themes across all TCs' initial philosophy statements from the beginning of the semester and the common elements of TCs' philosophy statements from the end of the semester (Strauss & Corbin, 1990; Yi, 2018). Since the elementary TCs were directed to include an additional section on their philosophy statements at the end the semester addressing equity, diversity and social justice in science teaching, we used deductive coding to identify whether and to what extent elementary TCs discussed equity, diversity, and social justice explicitly in their final philosophy papers.

5.4 Changes in Teacher Candidates' Thoughts on Role as Teacher

The findings discussed here characterize the ways in which TCs represented value in diversity and equity in the science classroom through their DASTT images and science teaching philosophy statements. A brief characterization of TCs' DASTT checklist scores is offered below, followed then by a more in-depth look at emergent themes across their drawings. We conclude our discussion of the findings by exploring TCs' science philosophy statements and more deeply considering the equity-specific sections of the elementary TCs' end-of-semester statements.

5.4.1 Findings from Draw a Science Teacher Test

As mentioned previously, the DASTT checklist scores can range from 0 to 13, with a lower score indicating a more student-centered teaching approach (Thomas et al., 2001). The overall average DASTT checklist score on TCs' drawings at the beginning of their science methods course was 4.67 (4.64 average among elementary TCs; 4.8 average among secondary TCs), on the cusp between an exploratory (DASTT score 0–4) and conceptual (DASTT score 5–9) teaching style. According to Thomas and colleagues' teaching styles continuum, a teacher with an exploratory style "believes students are capable of managing their own learning; curriculum is open to student interests; teacher leads and guides student activities/investigations; teacher focuses on student questions as an instructional goal; [and] alternative assessment measure student learning and knowledge" (p. 310) whereas with a conceptual teaching style, the "teacher believes student need themed, conceptual learning experiences; content is exploratory, organized around key concepts; teacher organizes the connections of content and processes of science; teacher-centered lessons include hands-on activities, group work, and discussion of ideas; tests check for understanding of important concepts" (p. 310). The overall average DASTT checklist score on TCs' drawings at the end of their science methods course was 3.48 (3.36 average among elementary TCs; 4.25 average among secondary TCs), indicating an exploratory teaching style. The decrease in DASTT scores from the beginning to the end of the courses indicates that the teaching style conveyed in TCs' drawings became more exploratory and student-centered over the course of their science methods course. We did not run a paired sample t-test for the elementary group because the data were not normally distributed. We ran only descriptive statistics for the secondary group due to the small sample size.

To further unpack this shift, we revisited TCs' drawing and informed by our theoretical framework and ambitious science teaching, used deductive coding to look at the nuance of what changed. Three predominant themes emerged with regard to changes in TCs' DASTT from the beginning to the end of our courses. Specifically, we observed (a) more student focus, (b) more markers of discourse, and (c) more tools of science in students' hands in TCs' later drawings.

Over the course of the semester, there was a shift in *who* (the teacher or the students) was centered in TCs' drawings, with TCs' later drawings being more student focused. In drawings from the beginning of the semester, the teacher was generally placed front and center. In drawings from the end of the semester, the teacher was no longer the focus of the drawing, and rather than being the focus were drawn to the side or among students. Figure 5.1 showcases a unique lens for centering the students. Unlike other representative examples included in this chapter, this TC's drawings did not include students as a part of their instruction as shown in Fig. 5.1;

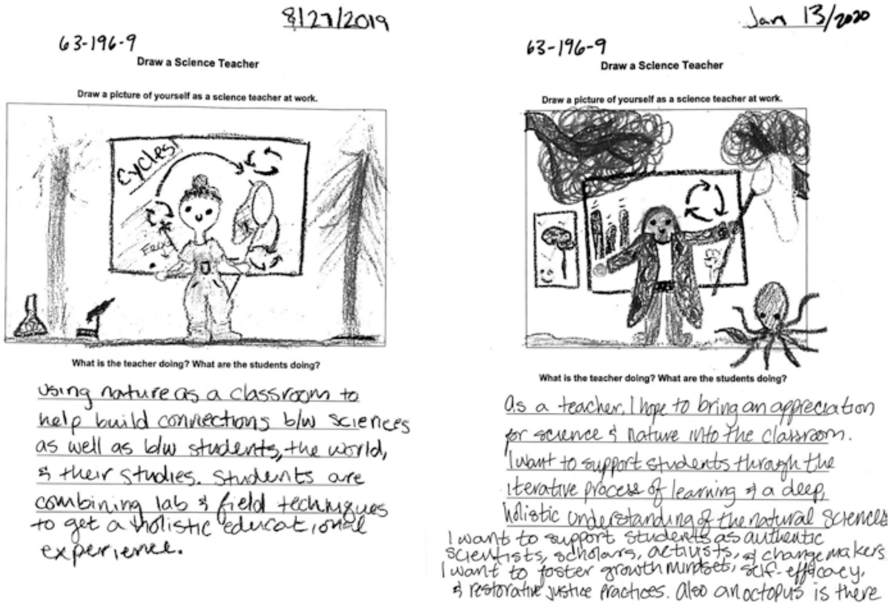

Fig. 5.1 Secondary TC's drawing from the beginning (left) and the end (right) of a semester-long science methods course. Description for drawing on left: Using nature as a classroom to help build connections between science as well as between students, the work, and their studies. Students are combining lab and field techniques to get a holistic educational experience. Description for drawing on right: As a teacher, I hope to bring an appreciation for sciences and nature into the classroom. I want to support students through the iterative process of learning and a deep, holistic understanding of the natural sciences. I want to support students as authentic scientists, scholars, activists, and change makers. I want to foster [sic] growth mindset, self-efficacy, and restorative justice practices Also an octopus is there

rather, it is the TC's descriptions that shift to include a more holistic and engaged perspective on the TC's students.

Not only did TCs decentralize the teacher's position in the classroom, but their drawings from the end of the semester also featured more markers of discourse or talk moves (Windschitl et al., 2018). Drawings from early in the semester often included teachers asking questions to the whole class or small groups. These questions were generally interpreted to be unidirectional—the teacher asked; the students answered. Yet, in drawings from the end of the semester, we see a more distributed pattern of talk, one in which multiple voices and ideas are included. Figure 5.2 showcases a representative example of a TC's drawings that demonstrate these first two themes: the decentralization of the teacher and the inclusion of talk moves that seem to break an otherwise-presumed initiation-response-evaluation (I-R-E) pattern of discourse.

The final trend in shifts in TCs' drawings from the beginning to the end of the semester was the inclusion of more tools of science in students' hands. Often the inclusion of science tools accompanied a shift in who was the focal point (the

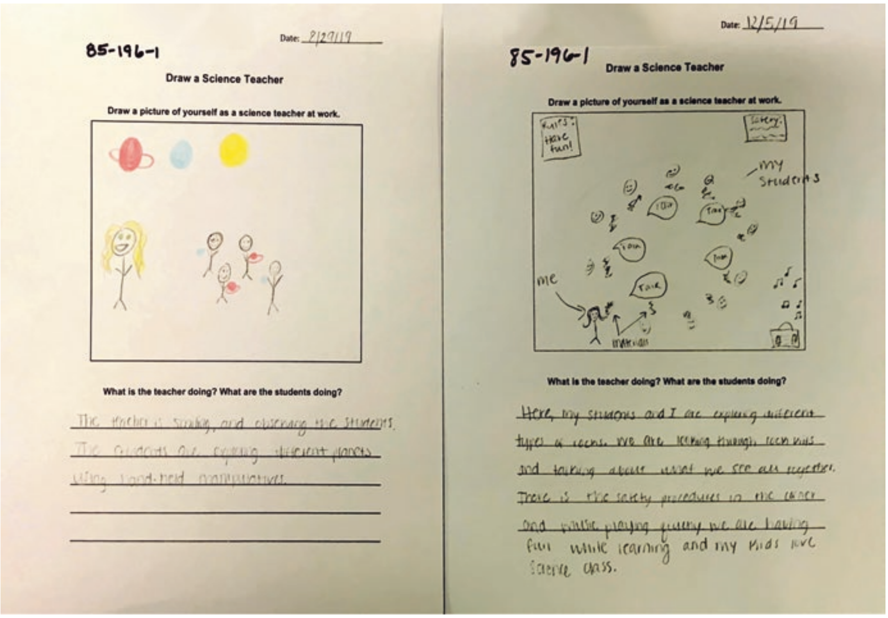

Fig. 5.2 Elementary TC's drawing from the beginning (left) and the end (right) of a semester-long science methods course. Description for drawing on left: The teacher is smiling and observing the students. The students are exploring different planets using hand-held manipulatives. Description for drawing on right: Here my students and I are exploring different types of rocks. We are looking through rock kits and talking about what we see all together. There is the safety procedures in the corner and music playing quietly. We are having fun while learning and my kids love science class

teacher or the students) of the drawing and whether the students were depicted as passive or active agents in the science learning process. Figure 5.3 showcases a representative example of each of these three trends in a TC's drawing. From the first to the second drawing, we see the teacher decentralized, more opportunities for student interactions and talk, and more tools of science in use by students.

5.4.2 Findings from Science Teaching Philosophy Statements

The general prompt for TCs' science teaching philosophy statement was: "*Based on your own experiences, define your science teaching philosophy. In other words, how would you describe what encompasses good science teaching? What personal and professional characteristics are important for good science teaching? How do you know students have learned? What opportunities do students have to learn in different ways? How do you ensure that ALL students have the opportunity to learn?*" Across TCs' responses to this general prompt, we noticed shifts across TCs' science teaching philosophy statements from the beginning to the end of our science

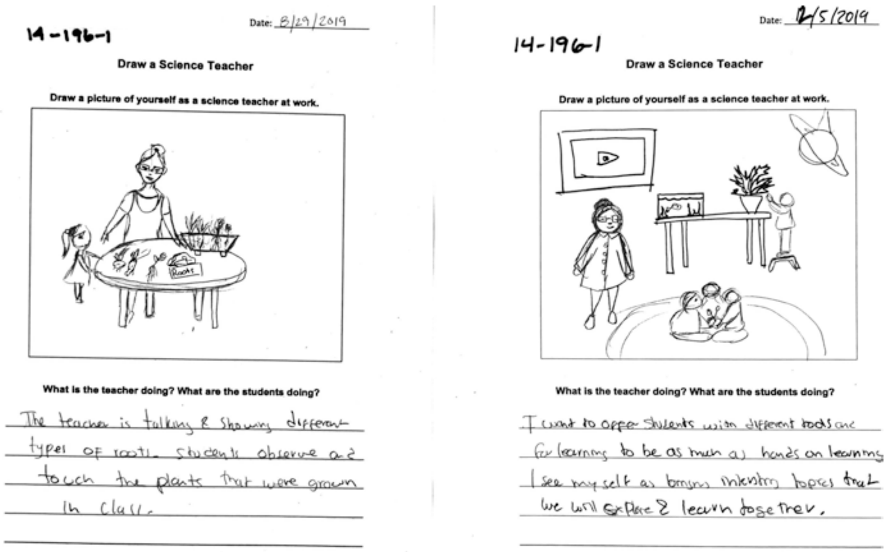

Fig. 5.3 Elementary TC's drawing from the beginning (left) and the end (right) of a semester-long science methods course. Description for drawing on left: The teacher is talking and showing different types of roots. Students observe and touch the plants that are grown in class. Description for drawing on right: I want to offer students with different tools and for learning to be as much as hands-on learning. I see myself as bringing interesting topics that we will explore and learn together

methods courses. Some of these shifts seen in the philosophy statements parallel those from the DASTT (Thomas et al., 2001). Specifically, TCs decentralized who the main, important players are in the classroom. Their philosophy statements became more student-centered and more active (rather than teacher and student as passive) during the semester, and an exploratory orientation (Thomas et al., 2001) became more apparent. Additionally, ambitious science teaching connections were evident as TCs wrote about asking "how" and "why" questions, eliciting students' ideas, and asking thought-provoking questions during class discussions—all of which would be done through a teacher's use of talk moves based on conversational goals (Windschitl et al., 2018).

We also identified themes that supplemented our developing pictures of TCs' commitments to equitable science teaching (based on course artifacts). Specifically, we observed TCs (a) discuss the teacher as a learner; (b) describe science as an inviting, accessible, inclusive discipline and space; and (c) draw connections to science and engineering practices and nature of science. These themes are discussed below.

5.4.2.1 Teacher as Learner

There seemed to be a consensus among TCs that “people that teach science should be able to ask questions along with their students” (Elementary TC 15) and “be passionate about learning” (Secondary TC 68). Inherent to this notion of the teacher as questioner/learner is staying abreast of developing scientific ideas by “reading and watching new ideas form within our discipline will be key to knowing what is happening to change our collective understanding of the world around us. Teaching science means keeping up with new discoveries and then explaining how this may support or change our understanding of current theory” (Secondary TC 92). The TCs “hope to have a contagious passion for learning, not just about science, but about all things” (Secondary TC 63).

5.4.2.2 Science as an Inviting, Accessible, Inclusive

In modeling for their students a passion for questioning and learning, TCs portrayed science as an inviting, accessible, and inclusive discipline and space. “Science as a subject naturally is very inviting for those who are curious and have a lot of questions” (Elementary TC 07), and TC discussed ways to recognize and celebrate all that students bring to the science classroom: “Students have always been scientists, but now they are also question-askers, risk-takers, artists, writers, investigators, advocates, and activities; connecting life experiences to science” (Secondary TC 63). “Science does not live in a vacuum” (Secondary TC 92), so TC discussed building on students’ lives and interests and cultivating a positive and supportive classroom community as ways to present a broad and accessible image of science to their students. In doing this, teachers “should not create a superiority complex or create an environment that does not allow for students to share their ideas or ask questions. Rather teachers should be welcoming and nurture an environment that welcomes mistakes” (Elementary TC 15).

5.4.2.3 Science and Engineering Practices and Nature of Science

This notion of welcoming, making, and learning from mistakes was also evidence in the connections TCs drew to science and engineering practices and nature of science. Specifically, “science isn’t about right versus wrong but rather why something is the way it is and discovering with an open mind” (Elementary TC 01). When this aspect of the scientific endeavor is clear, “students will be willing to take those risks and ask those questions that will ultimately form their thoughts and understanding of the scientific world” (Elementary TC 07). In fact, “science teaching should be geared towards helping students ask more questions and also answer some of these questions” (Elementary TC 15) by “using scientific processes to solve them” (Secondary TC 63). With this approach, TCs “hope that...students will see that science isn't just for White men in lab coats with beakers, but that they themselves have been, and will continue to be, scientists for their whole lives" (Secondary TC 63).

5.4.2.4 End-of-Semester Philosophy Statements

Some initial miscommunications related to the final science teaching philosophy prompt prevent us from taking a deep look across both the elementary *and* secondary science methods courses from the beginning to the end of the semester. Specifically, the elementary TCs were provided an additional prompt for the end-of-semester science teaching philosophy statement to address equity, diversity and social justice in science teaching specifically. Because the secondary TCs did not receive this additional direction, the discussion that follows is specific to the elementary TCs' final philosophy statements. Again, we used deductive coding to identify whether and to what extent elementary TCs discussed equity, diversity, and social justice explicitly in their final philosophy papers. Specifically, their responses fell into four categories: (a) those that did not address equity, diversity, and social justice (8%); (b) those that acknowledged student differences (20%); (c) those that discussed the importance of classroom community (24%); and (d) those that emphasized meeting students where they are in order to support learning (48%).

The responses that did not address equity, diversity, and social justice directly or explicitly instead focused on instructional objectives and learning styles. For instance, "I hope to use whole brain teaching methods within my future classroom so that students remember vocabulary through kinesthetic learning" (Elementary TC 10) and "There are many ways to give students the opportunity to learn science, whether it be visual, kinesthetic, audio, etc. In my opinion, I believe that science should be fun. Students need to be engaged and their minds need to be stimulated" (Elementary TC 11). Those TCs who acknowledged student differences generally did so with regard to students' identities, cultures, and abilities:

> Understanding a student's culture provides context for the learner through what is valued in society and certain expectations that a student may adhere to. A child is a product of their environment and experiences and thus students may bring prior cultural knowledge that should be acknowledged and accepted. (Elementary TC 84)

For TCs who acknowledged and saw as a strength students' diverse abilities, experiences, and backgrounds, availability of diverse materials and differentiation were key parts of their science philosophy statement. Representative responses of this aspect of science teaching acknowledge,

> there are many things that we must be mindful of and making sure that our classrooms inclusive is very important. It is our job to embrace the diversity that is among us and make sure that everyone is included in every part of our days. Having a diverse variety of literature that supports our science learning is a wonderful place to start. (Elementary TC 5)

Nearly one-quarter of the elementary TCs took the idea of acknowledging student difference and applied it to the classroom community. For instance,

> The classroom needs to be a place where students feel like they can be themselves and somewhere they are not excluded in any way, shape, or form. Students are going to be coming into the classroom with all different types of backgrounds that all deserve respect from other students and most importantly their teacher. It is important as a teacher, to set up your classroom community in a way that students feel like they are important members of the classroom. (Elementary TC 1)

This can be accomplished through "tak[ing] the time to truly get to know my students. Their backgrounds, culture, religion, what they believe in, what they've experienced...When students feel included and validated, they are more likely to want to be involved and excited about their learning" (Elementary TC 34). Getting to know students as well as including and "discussing [marginalized scientists] in your room can allow students to feel more comfortable and learn more about the realities of our world" (Elementary TC 76).

Finally, nearly one-half of elementary TCs discussed the need to meet students where they are in order to support learning because "every child deserves to have an equitable opportunity to learn, be heard, and show their intelligence" (Elementary TC 86). Within responses in this category, several TCs were explicit in the distinction between equality and equity: "Understanding that not all students need the same thing, and equity is more important than equality is key in to taking the step and differentiating lessons and curriculum" (Elementary TC 7). Further, "Another aspect that I think is really important is equity vs. equality, meaning that fair isn't always equal. Every student has different needs, and what might be fair for one student simply may not be fair for another because of their needs" (Elementary TC 17). The critical importance of acknowledging student differences and meeting students where they are is to open up, rather than limit, students' participation in science. Specifically,

> Science should allow all students of all social and economic backgrounds to be able to participate and feel as their ideas are valid and heard. Educators should make sure that [homework] and other class activities don't only connect to the experiences of only a few. Educators need to take into account the diversity and the access to learning tools are not all equal outside the classroom. (Elementary TC 14)

5.4.3 Summary of Findings

Over the course of the semester, TCs incorporated elements of equitable and ambitious science teaching in both their drawings and philosophy statements. Specifically, in TCs' drawings we observed more student focus, more markers of equitable discourse, and more tools of science in the hands of students from the beginning to the end of the semester-long science methods courses. These observations also coincided with a decrease in the average DASTT score (Thomas et al., 2001) from the beginning to the end of the semester, indicating the teaching styles depicted in TCs' drawings became more exploratory and student-centered over time. An exploratory, student-centered approach to science teaching was further echoed in TCs' science teaching philosophy statements. In their statements, TCs also discussed the role of teacher-as-learner; described science as an inviting, accessible, and inclusive discipline and space; and drew connections to both science and engineering practice as well as nature of science. Additionally, a more focused examination of the ways in which elementary TCs' addressed equity, diversity, and social justice in their end-of-semester philosophy statements revealed that more TCs than not emphasized that meeting students where they are in order to support learning was essential to an equitable and culturally responsive science classroom.

5.5 Impacts of the Action Research on the Teacher-Scholars

It was not only our TCs' representations of equity, diversity, and social justice that changed during this study. Both of us as teacher-scholars have also been impacted by the focus on centering equity, diversity and social justice in our science methods courses. We continue to make incremental changes to the course based on our findings and reflections on our teaching. Below, we share our personal insights on the ways in which our engagement in this action research project has affected our teaching, research and service.

5.5.1 Joi

Since we started this journey, I have only sought to learn more about how I can confront issues of racism, and learn more about equity, diversity and social justice. For example, I have attended workshops related to racism and learning more about specific groups including Black studies, Latinx students and Indigenous science to inform my teaching, research and service. It has also spurred me to be active in making changes based on this new knowledge. I am now Chair of our College of Education (COE) Diversity Council. As a part of the work of the diversity council, I have increased my advocacy efforts for all students, and our Students of Color in the COE by starting the Future Teachers of Color (FToC) organization. FToC provided professional development geared specifically towards the needs of Students of Color and opportunities to speak with leadership, including the Dean, about issues they face in the COE. In relationship to this work, I have coordinated with the Educational Support Center, which does the practicum and student teaching placements for our teacher education programs to provide placement for FToCs in diverse classrooms, with Teachers of Color or effective teachers of Students of Color. In addition, I am a part of a subgroup of the diversity council who provide workshops around identifying microaggressions and microaggression interventions across the university.

5.5.2 Angela

Living the mantra of "know better, do better," this work has led me to reflect on my years as a high school science teacher. I am proud of some things I did related to equity, diversity, and social justice; other memories make me cringe. Since we started this journey, I have sought to engage in my own self-work related to issues of race and racism—including how I perpetuate White supremacy and what I can do to work to dismantle racist systems, policies, and practices. I have joined campus discussions and reading groups, attended external workshops and talks, and turned inward to reconsider my experiences, perspectives, and positionality. I have also joined the COE Diversity Council as one way to move my self-work to action. Additionally, as I continue to unlearn, learn, and relearn, I draw these experiences into my classes, shining some light on the inner and outer process of continually working to better center equity and justice for my White students. Whereas nearly all of my students are White and a majority of the students in their practicum classrooms are White, I strive to show my students that equity and justice are always important.

5.6 Discussion and Implications

In this action research, we sought to explore how TCs express value in diversity and equity in the science classroom and how they embrace learning opportunities relevant to diversity, equity, and social justice. By disseminating this unfunded work, we are optimistic that, with our future grant proposals, funding agencies and publishers can appreciate the implications of this action research and its importance for the ever-diversifying science classroom. We recognize that limited, present-day opportunities for disseminating this work may improve as the climate is changing in relationship to publishing studies with equity, diversity and social justice as an important focus in science education. In addition, a major United States funding agency has put out a call focused on racial equity in STEM education. Therefore, it is our hope that opportunities to publish and fund these kinds of work may become readily available in the future. More importantly, this work is imperative. TCs need opportunities to delve into culturally relevant pedagogy in both their coursework and their field-based practicum placements. Thus, there is need to support both preservice and inservice teachers to meaningfully engage with culturally relevant pedagogy on an on-going basis.

We were able to identify a shift in TCs' thinking about equitable science instruction across both assignments (DASTT and science teaching philosophy statements) from the beginning to the end of our semester-long science methods courses, especially regarding aspects of culturally responsive teaching (Villegas & Lucas, 2002) and ambitious science teaching (Windschitl et al., 2018). Particularly, TCs' drawings and philosophies reflected affirming views of diversity; a desire to know the lives of their students; ownership of the responsibility to make their classrooms and schools more accessible, inclusive, and equitable; and recognition that they need to build their instruction on what students already know—all characteristics of culturally responsive teachers (Villegas & Lucas, 2002, p. 20). Concerning ambitious science teaching, TCs' came to center equitable classroom discourse with the use of talk moves and student-to-student talk (Windschitl et al., 2018) and integrate science and engineering practices as well as components of nature of science. TCs' identification of specific ambitious science teaching practices may indicate that they are connecting with the equity focus of ambitious science teaching—opportunities for all students to participate in the practices of science (Windschitl et al., 2018). Additionally, CRT has been an invaluable framework for helping make changes to our respective courses. Our work has also impacted us, as teacher-scholars, as we continue to seek resources to learn and improve our practice.

Although the DASTT checklist enabled us to identify changes in TCs' represented teaching styles (exploratory, conceptual, or explicit; Thomas et al., 2001), our experience using the checklist within the context of this study highlights a need for it to be modified to better capture *equitable* and *ambitious science teaching*. For instance, lower scores on the checklist are intended to be associated with a more desired, student-centered teaching style (Thomas et al., 2001); yet low scores can also be received due to a lack of details or a drawing that depicts science teaching outdoors instead of inside the classroom. Additionally, the checklist only notes that science tools and materials are present, with no attention given to who (the teacher, the students, no one) is using them. Finally, based on the checklist, a higher score (indicative of more teacher-centered teaching) is given for depictions of teacher questions. From ambitious science teaching (Windschitl et al., 2018), we recognize that talk is a tool for learning, and teacher questions and talk moves are inherent to and invaluable in the sense-making process. Although the intent of questions or portrayed talk (i.e., I-R-E pattern of discourse or talk as a tool for learning) may be hard to discern in TCs' drawings, the checklist does not adequately allow for and capture the talk moves of ambitious science teaching. The binary (present/not present) coding of the DASTT checklist lacks some of the nuance needed to explore and examine TCs' culturally responsive (Villegas & Lucas, 2002) and ambitious (Windschitl et al., 2018) science teaching.

During his 2021 presidential address to the American Educational Research Association, Dr. Shaun Harper laid out, in no uncertain terms, that "as citizens and scholars we have a responsibility to destroy evil in all its forms, including in an evil education." The evil education he described is one marked by racism, sexism, xenophobia, transphobia, among other things; that is, an education that does not authentically center diversity, inclusion, equity, or social justice. For each example we can recall of evil in classrooms, schools and school districts, the teachers, principals and superintendents implicated in micro- or macroaggressions went through programs similar to the ones in which we teach. Therefore, we, as teacher-scholars, sit in a unique and important position in the fight to end the current epidemic of racial injustice (Harper, 2021). Revamping our science methods courses to better center equity, diversity, and social justice is one element of our equity-focused professional and personal work. Although the COVID-19 pandemic has impacted this work, like it has much of higher education, we have continued to reflect on and improve our courses to better support TCs in becoming equitable science educators.

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Chapter 6
Exposing Inequities Within Teacher Professional Development and Its Impact on Advancing Equity, Diversity and Social Justice in STEM Education

Regina L. Suriel and Kristy Litster

6.1 Introduction

The call to develop a more scientifically literate society in the United States has been prominent for decades. Scientific literate individuals are those who draw on the knowledge and practices of science, such as using epistemologically sound reasoning to ask questions or seek evidence-based explanations to gain an understanding of current or new knowledge regarding natural phenomena (Next Generation Science Standards, Lead States, 2013). In this effort, scientific literate individuals use their critical thinking abilities to engage in personal decision making that affects their personal wellbeing, that of others when engaging in science-based social issues, and that of the planet by supporting eco-friendly practices and behaviors (National Academies of Sciences [NAS], 2016; Yacoubian, 2018).

Scientific literacy in the United States has also increased economic productivity through the development and utilization of knowledge and products that better our existence (National Academies of Sciences, Engineering, and Medicine, 2016). As such, industry benefits from individuals who can draw on science and different disciplinary literacies such as mathematics, technology and engineering or STEM literacies. In fact, the need for STEM professionals has risen in the past decades to address more complex societal and technological issues, such as effectively addressing climate change and healthcare concerns (Knipprath et al., 2018). However, the US is not developing enough STEM professionals from diverse cultural

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backgrounds (Kennedy et al., 2021). A lack of culturally diverse STEM professionals limits the kinds of perspectives and approaches needed to solve everyday problems (NGSS, 2013). This effect is due in part to a lack of targeted educational efforts to adequately prepare teachers to teach the next generation of STEM literate students. Teachers are often hindered by a STEM knowledge gap (Aguirre-Muñoz et al., 2021; Madani, 2020). Thus, STEM teachers' professional knowledge needs to be reexamined to address teachers' needs for enacting effective STEM instruction.

Efforts to support STEM education have been placed at the forefront of many educational and funding initiatives; however, many hurdles have prevented the implementation of effective STEM education and teacher training (Margot & Kettler, 2019), particularly with educators teaching traditionally marginalized students from low socio-economic status (low-SES) and culturally and linguistically diverse (CLD) backgrounds. At the root of these hurdles are educational inequities evident in the disproportionate availability of intellectual and instructional resources offered to these students (Banilower et al., 2018). In this chapter, the authors first present our theoretical underpinnings of critical cross-cultural education. This is followed by a discussion on various structural inequalities that prevent equal access to available resources. We then discuss the current state of STEM PD in the state of Georgia to highlight the lack of funding and accountability measures for the implementation of the approaches introduced regarding STEM education and social justice agendas. We also present examples of our successes with teaching STEM despite receiving little to no funding. We highlight the STEMITL project, a small-funded project, as an example for integrating STEM curricula and share study findings to showcase the importance for modeling STEM curricula with preservice teachers. We also discuss examples of math method course assignments for integrating STEM. Lastly, we share our challenges seeking grant funding targeting STEM-based PD for local, rural teachers. We conclude with recommendations for grant funders of STEM-based professional development targeting equitable and socially just practices.

6.2 Inequities in STEM Education

6.2.1 Theoretical Underpinnings

Historically, pervasive structural inequalities are often felt by students from low-SES and CLD backgrounds attending public schools in the United States (Urrieta & Villenas, 2013; Valencia, 2010). According to Valencia (2010), structural inequalities exist when powerful groups and individuals, such as legislators and school board members, fail to optimize and provide equal educational opportunities for CLD and low-SES students. While many paradigms exist that examine power relations and their effects on institutionalized inequities for CLD and low-SES students, we draw on critical cross-cultural education as a theoretical framework for exploring how social change can be brought on by teaching about power dynamics between different cultural groups (Rodriguez & Morrison, 2019). For social change to occur, educational policies and practices must support diversity, equity and social justice. Rodriguez and Morrison (2019) define diversity as "the recognition of physical and social characteristics that make individuals unique and celebrating this uniqueness as a source of strength for the community at large. They also define equity as "the enactment of specific policies and practices to ensure equitable access and opportunities for success for everyone" (p. 28). Equitable access in science education, according to the National Research Council (NRC, 2012) means that students are provided with quality teachers and instruction, time, space and material resources to learn and engage in science and engineering practices. Lastly, Rodriguez and Morrison (2019) define social justice as the conceptual framework guiding the enactment or specific policies and practices to promote diversity and equity.

Social justice education is aligned with critical theory and focuses on examining diversity and equity issues, with the aims to dismantle the powers sustaining structural inequalities and to empower teachers and students to enact change (Freire, 1998; Giroux, 1983). This change can be exercised in various forms, for example when engaging in knowledge construction or engaging in activism (Ladson-Billings, 1992, 2014). Professional Development on social justice education is another form of social justice engagement that can help develop teachers' understanding of structural inequalities and anti-racist, anti-classist, anti-deficit views (Dover et al., 2020; Morales-Doyle, 2016). Also, teachers can be assisted with transforming curricula that provide students opportunities to examine how power affects the kinds of knowledge that are valued and those that are ignored (Dover et al., 2020). Moreover, with PD that focuses on utilizing students' Funds of Knowledge (González et al., 2005), science teachers can enrich curricula from diverse perspectives so that students: (a) feel included and validated when their inherited cultural knowledge is part of the curricula they learn; (b) apply their understanding of science to explain the natural world; (c) use this knowledge to engage in civic and personal duties that impact their well-being; and (d) enact change to disrupt oppressive practices and behaviors (Banks & McGee Banks, 1993; Ladson-Billings, 1992; Suriel & Freeman, in press). Funds of Knowledge refers to the cultural knowledge that individuals possess and that has been inherited or experienced and utilized to make sense of the world (González et al., 2005). Though much more is known now about what is needed to change existing structural inequities in education, socially unjust practices relating to high quality STEM instruction for the low-SES and CLD students persist (National Academies of Sciences, Engineering, and Medicine, 2016). In the next section, we present four sources of evidence that illustrate how social inequities are manifested through structural inequities.

6.2.1.1 Student Performance on STEM-Based Standardized Exams

One source of evidence of structural inequalities is the resulting student performance on STEM-based standardized exams. National measures of student learning outcomes based on standardized tests consistently show that on average, students from low-SES and CLD backgrounds underperform academically compared to their wealthier and White peers (Hanushek et al., 2020). For example, the National Assessment of Educational Progress (NAEP) report that CLD and low-SES students, on average and across the grades, scored around 30 points lower compared to their counterparts on the NAEP science, technology, engineering and mathematics assessments (National Science Board [NSB], 2018). Consequently, academic underperformance among low-SES and CLD students affects their prospects for enrolling in advanced STEM courses in high school, entering postsecondary education and earning college degrees, particularly in lucrative STEM fields (Mau & Li, 2018). Investments in STEM education are expected to grow; low-SES and CLD students are at a disadvantage if they are unprepared to meet this growing demand for STEM professionals (National Science Board [NSB], 2020).

6.2.1.2 Inadequate Learning Resources

A second source of evidence for structural inequalities for the low-SES and CLD students is decreased funding for education preventing access to learning resources. In the state of Georgia, for example, funding for education has been substantially cut 10.2 billion dollars in the last two decades (Lee and Georgia Policy Institute, 2020). Cuts on educational funding affect the quantity and quality of learning resources, which are much needed to learn STEM. The effects of limited funding for learning are even more prominent in light of the COVID-19 pandemic school closures. Studies on school-related pandemic restrictions revealed that children in low-SES areas did not have adequate resources to continue learning (Clark, 2018). In fact, an increased learning loss has resulted for low-SES and CLD students who lacked school-provided personal digital devices and internet connectivity to continue learning from home (Kaffenberger, 2021).

6.2.1.3 STEM vs. Non-STEM Programs

A third source of evidence of structural inequalities for low-SES and CLD students can be noted in the limited access to STEM-based enrichment programs, which restricts the participation of students who may need it the most. For example, in the state of Georgia, the student population in public schools are majority CLD students and low SES (Georgia Department of Education [GADOE], 2021). While there is a noted 1000% increase in the number of STEM certified schools in the last decade in the state of Georgia, approximately 3% of public schools are STEM/STEAM certified (STEM/STEAM Georgia, n.d.). The lack of access to STEM schools, particularly for Georgia's CLD students limits their opportunities to quality STEM curricula.

Moreover, STEM-based programs often require that students demonstrate high cognitive aptitude in program entrance exams. These exams, or evidence of participation on highly rigorous courses may be unattainable and may serve as barriers for low-SES students and English language learners who may not have access to the same resources and social capital as their wealthier and White peers (Coleman, 2020). Structural inequalities have prevented the access to enriching resources that can make these students competitive for these opportunities. Lastly, compounding this issue is the abstruseness of targeted funding for non-STEM-focused programs. STEM-based programs are often funded and additionally supplemented by public and private grants; however, it is not clear how much funding is provided to develop STEM literacy in teachers and students who do not participate in STEM-focused programs.

6.2.1.4 Unprepared Teachers

Lastly, a fourth source of evidence of structural inequalities often experienced by CLD and low-SES children is instruction that does not address integrated STEM nor reflect students' funds of knowledge, which may serve to disengage them from learning. It is well documented that teachers are not adequately prepared to teach STEM (Madani, 2020) or social justice education (Fabionar, 2020). While social justice education has been professed, teacher training on social justice education is still not prominent in teacher education programs. Teaching for social justice in Teacher Preparatory Programs has been a challenge for various reasons.

A challenge that many Teacher Preparatory Programs (TTP) face is that institutions of higher education may not prioritize social justice education, particularly in the current political climate where teaching for social justice has been an unduly incendiary political topic for some. Also, TTP may offer only a single course addressing student diversity, but many of these courses are non-specific to effective disciplinary instruction and may not emphasize the eradication of educational inequities experienced by low-SES and CLD learners. For example, these courses may not emphasize how teachers can: a) draw on students' cultural assets to teach and engage learners with STEM; b) engage students in examining STEM curricula for diverse perspectives, particularly from CLD scholars, and in doing so, rewriting more balanced narratives representing diverse funds of science knowledge (Razfar & Nasir, 2019); and c) create and support equitable STEM learning environments. Teacher educators are also partly to blame for this lack of teacher preparation in that they themselves may not possess the knowledge to teach for social justice within science education (Underwood & Mensah, 2018). In sum, a lack of focused teacher preparation targeting CLD and low-SES students is due in part to interest convergence, policy making that supports hegemonic supremacy (Dixson & Anderson, 2018; Urrieta Jr., 2009) and deficit thinking about what teachers can or cannot learn (Valencia, 2010). Thus, STEM teachers are unprepared to effectively teach CLD and low-SES children in ways that draw on their cultural and inherited assets (Banilower et al., 2018; Suriel & Atwater, 2012).

6.2.2 Development and Use of Intellectual and Material Resources for STEM Education

To address these disparities, a few initiatives have been implemented, to varying degrees of success. These initiatives range from providing nutrition, added human resources, and high-quality curricula. Curricula here refers to all materials and modes of instruction that support high quality teaching and learning. High-quality curricula are those that address and optimize national or state-mandated content standards and are developmentally appropriate, cognitively demanding, and culturally and linguistically accessible (Steiner et al., 2018). According to the Next Generation Science Standards (NGSS, 2013), a high-quality science curriculum is one that integrates STEM. STEM education emerged to develop teacher's knowledge for integrating STEM disciplines. However, various studies report on the challenges for conceptualizing and enacting STEM education, due in part to the various demands for discipline specific knowledge and skills. In fact, many teachers struggle with defining STEM education (Holmlund et al., 2018). However, targeted professional development with a combination of content knowledge and teacher feedback can help develop teacher knowledge and skills for teaching and integrating STEM topics (Aguirre-Muñoz et al., 2021; Madani, 2020; NSB, 2020). Next, we discuss elements in professional development crucial for supporting teachers working in impoverished schools.

Professional Development Professional development (PD) is offered to employed teachers to support ongoing professional growth. PD is provided by educators and school leaders at the school, district, state and national levels and is often required to gain recertification of teaching credentials (Georgia Professional Standards Commission, n.d.). PD that targets the development of pedagogical content knowledge (PCK) is essential because it increases teachers' confidence in teaching the content and implementing highly effective practices that best support student content learning (Kang et al., 2018). Along with increasing content knowledge by participating in PD, teachers can also learn new skills such as using new technologies and resources. Professional Development can also help increase teachers' positive attitudes towards integrating STEM curricula and their ability to collaborate with colleagues, which are two key aspects to ensuring continued and enduring implementation practices (De Meester et al., 2020; Thibaut et al., 2018).

Some PD provide teachers with additional resources to teach in novel ways. In ideal classroom situations when teachers use available resources effectively, such as laboratory equipment or digital tools, they maximize instructional value. However, for teachers working in impoverished schools, opportunities to participate in PD are often minimized for different reasons including geographic isolation or school-bound commitments that prevent them from participating. For example, teachers working in impoverished schools may not be funded for travel and lodging to attend PD in distant locations or may not be released from teaching because limited funding for teacher substitutes (Banilower et al., 2018). As such, structural funding inequalities prevent these teachers from professional growth and access to free instructional resources.

Need for Quality PD and Resources Lack of quality and access to instructional resources and PD prevents teachers from providing high-quality curricula (Owens and Georgia Department of Education, 2015). Often, teachers in low-SES schools use their own monetary funds and their own ingenuity, including household items or free-of-charge resources to provide students with authentic STEM learning experiences. Teachers' ingenuity can be confined within teacher professional agency, or "teachers' initiative and decision making to reach a certain end" (Bandura, 1986; Eteläpelto et al., 2013, as cited in Imants and Van der Wal 2020, p. 61). Thus, when nestled in a positive school ethos, teachers' PCK, effective use of resources, and teacher professional agency for maximizing learning are high priority instructional elements for supporting teachers and student learning (Maclellan, 2016). It is this kind of disposition that teachers working in impoverished schools rely on to enhance STEM instruction. Though a great asset, teachers' overreliance on ingenuity should not be the norm to teach science effectively. Rather, teachers working in schools with limited funding, above all, should be supported with quality PD and resources to provide quality instruction to their students. Thus, it is imperative that in addition to increasing PD and resources for teachers working in impoverished schools, policies, practices, and educational funding should also target the development of school leaders' critical consciousness to enact much needed social change regarding teacher training and resource availability (Dover et al., 2020). In this effort, the possibilities for a school ethos of supporting social justice education and teachers' professional agency for enacting high-quality curricula are maximized (Maclellan, 2016; Rodriguez, 1998, 2015).

6.2.3 Funding and Accountability Measures for Training STEM Teachers in Georgia

Tracking of educational funding for teacher professional growth is a complex endeavor because monies are gathered from different sources; that is, private and government agencies, and partitioned though elaborate funding formulas. For example, different government monies are appropriated to support high quality STEM education. Title II Part A federal funds appropriate monies to states to further develop teachers' PCK in math and science. In the state of Georgia, Regional Educational Service Agencies (RESAs) utilize Title II funds to conduct teacher PD. Also, Title II Part D federal funds allocate monies to improve technology use in schools. To supplement funding needed to support curriculum quality, school leaders can also appropriate other kinds of available funding from other sources. Lastly, additional public funding can also be gained by some educational systems that have "more experienced and more educated teachers" (Rubenstein & Sjoquist, 2003, p. 15), and through merit-based, performance pay bonuses for individual STEM teachers (Jones & Hartney, 2017). However, merit-based and performance-based funding accentuates persistent social inequities often experienced by teachers working in impoverished school systems. It is often the case that social capital is minimized in impoverished schools because they have historically been unable to attract and retain highly qualified teachers and often lack STEM-based materials and funding to carry out highly effective instruction. These conditions often deter highly qualified teachers from working in these schools (Clark, 2018).

In the past, STEM PD in Georgia was often conducted by RESAs through Math and Science Partnership programs (MSP). MSPs were funded through the No Child Left Behind Act-allocated funds for STEM education. In the advent of the Every Student Succeeds Act (ESSA) in 2015, funds for the MSPs were cut in 2018 and these monies were reallocated. Like public-school funding allocations, reallocated funding for PD in STEM education is difficult to identify due to complex funding formulas (Davis and Ruthotto 2019). In a recent and informal interview with a Southeast RESA director previously assisting with MSP teacher recruitment, Leah (pseudonym) mentioned not knowing where these current relocated funds exist.

However, RESAs continue to provide PD for teachers by offering physical and virtual workshops, and teachers can choose PD that is appropriate for their professional growth. In the teacher recertification process, which occurs every 5 years, Georgia teachers are expected to provide evidence of PD participation for professional growth. Established practices for determining which PDs teachers should complete are offered by supervising leaders; however, the onus for PD completion remains with the teacher. A teacher may choose to grow their expertise in any pedagogical or content areas, and not necessarily in STEM. Within the last decade, PD requirements for Georgia teacher recertification came to a halt. Between the years of 2011 and 2017, teachers were not required to evidence professional growth other than meeting PD expectations posed before 2011. Moreover, in the advent of COVID-19 pandemic restrictions, professional growth may have been redirected to develop needed skills for effectively carrying out virtual instruction. In essence, little to no accountability exists for STEM teachers to grow STEM competencies unless it is specifically suggested by leadership or teachers are motivated to do so.

6.2.3.1 Limited Accountability Measures for Professional Growth

Lack of accountability measures for STEM-focused professional development have hampered the kind of curricula teachers enact and low-SES, CLD students are often affected the most. While various agencies such as the National Science Foundation (NSF) and the US Department of Education provide STEM education funding opportunities through competitive grants, systemic underfunding of STEM teacher training particularly for teachers working in impoverished schools has been noted. The need to provide STEM-focused PD to teachers working in impoverished rural schools was important for two directors of a Southeast Georgia Math Science Partnership program (MSP). The authors share interview responses of the co-directors regarding this MSP. Both co-directors were faculty members at the university where the co-authors teach. Larry (pseudonym) is a previous science teacher and educator and director of the university's STEAM Center. Elena (pseudonym) is a seasoned math teacher, previous school principal and a now a retired math educator. The regional university sits in a small Southeastern city surrounded by produce and cotton farms. The university serves a diverse student population of mostly White and Black students and a small number of Latinx students. Across the state, the university is well known for its teacher education programs and is among the top education degree providers. The highly funded MSPs were carried out from 2004 until 2018, when MSP funding was officially terminated. The first author was also employed as a science instructor for the last 4 years of the MSP.

In an interview with MSP lead director Larry, he shared that he applied for MSP grants to provide much needed high-quality PD to local math and science teachers. This sentiment was also shared by Leah, RESA Math and Science PD director in her interview. Leah also stressed the need to provide MSP PD to rural teachers because they are often geographically isolated from one another, thus minimizing opportunities for networking and collaboration. Larry's efforts for targeted MSP PD were successful. The MSPs were well attended by math and science teachers. According to Larry, "When state funds were low to support the MSPs, local school districts appropriated additional funds to keep the program going." Larry attributes the success of the MSPs to highly engaging PD that incorporated effective use of technology, hands-on minds-on and inquiry-based activities. Larry shared that "Teachers learned math and science as students. They discovered it by themselves." He added, "Instructors' modeling of effective practices was the most important aspect of the PDs. Teachers often came to me to share what they had learned and applied in their teaching."

When Larry was asked about how participating teachers were held accountable for implementing the newly gained STEM knowledge, he explained that at first, there was no accountability for implementing what they learned in the PDs. However, over time, teachers began to be held accountable about implementing the strategies they learned by providing targeted feedback. When asked about accountability measures between PD they experienced and social justice agendas, Larry explained that in this regard, strengthening teachers' PCK was most important so that students experience success with highly trained teachers. But when asked about how teachers were held accountable for implementing high quality STEM curricula and tying these practices to student achievement, Larry explained that logistically, it was very difficult to hold teachers accountable. Larry shared that "There were too many teachers to track."

Codirector Elena corroborated Larry's understanding for the lack of accountability for STEM-based curricular implementation. In her interview about the MSPs she codirected, Elena first commented on her motivations for providing MSP professional development to local teachers:

> As I moved from single-system Teacher Quality professional development grants to the Math Science Partnership (MSP) grants, my colleagues and I realized how powerful a multisystem workshop for mathematics and science could be. Seeing the positive results of the

> summer workshops combined with the within-year activities motivated us to continue serving math and science teachers in the local RESA area for many years.

When asked how teachers were held accountable for the implementation of the STEM curriculum, Elena explained that

> Accountability measures for effective PD are implemented via an evaluative process. However, evaluating the efficacy of grant-based PD is difficult. The expectation of application of strategies is high, for both participants and leaders, during the PD workshops itself. Along with individual teacher resistance to curricular implementation, challenges with within-school teacher collaboration makes it nearly impossible to maximize the intended effects of the PD and to hold teachers accountable for implementing curriculum.

Elena goes on to explain that the MSP attempted to maximize the number of participating teachers at every opportunity, particularly from individual schools in order to encourage curricular collaboration and implementation. However, due to large geographical separations between the schools and the university, and limited collaboration from teachers within the school, it was difficult to track collaboration and evaluation of teachers. According to Elena,

> Teachers in the PD came from twelve or more school systems, and not all teachers in given groups were participants. For example, if a high school had six biology teachers and all six attended the workshop, the potential for systemic [curricular] change is very high. If only two or three of the six attended, the potential for change is greatly reduced.

Elena provides an example of a strategy that evidenced the implementation of the newly gained STEM-based PCK and its approaches that were introduced during the MSPs. She shares that,

> Some effective evaluation procedures were designed for some within-year activities and implementation of science-bound discovery activities. The required documentation included photo documentation of activities and photos of learning outcomes. The grant investigators and the evaluator felt that these requirements did hold teacher-participants appropriately accountable.

Elena elaborates her response to assert that "We all know that a few activities do not produce a consistent change. To affect any school change, systemic change is needed." When asked how teachers were held accountable for the implementation of socially just practices, Elena explained that,

> Socially just practices by teachers are potentially changed by PD activities and teaching, but it is probable that the most persistent influence on teachers' socially just practices come from the [educational] system, and more specifically from the teachers within their teaching department and school. Our professional development activities focused on providing mathematics and science experiences for all level students, including special needs students. For all MSP workshops, we ensured that teachers of students with special needs were participants. My opinion is that those who provide PD should be intentional in including cultural diversity training and resources. Maybe more importantly, teachers should be taught how to provide strong instruction to disadvantaged students. Modeling positive experiences in professional development can be a powerful motivation.

Elena's leadership for professional learning was heartfelt. Many teachers give credit to both Larry and Elena for the learning opportunities they experienced, and many teachers remain connected to the university as they seek additional PD opportunities. Larry and Elena's assertions acknowledge that although the MSPs brought successful learning opportunities to our local teachers, the implementation of the strategies learned from the MSPs were superficially measured or not accounted for at all. Most importantly, teachers were not provided the opportunity to examine existing educational inequalities in STEM education and how to best meet the needs of low-SES and CLD students that they serve.

As a science instructor with expertise within the MSP for 4 years, the first author focused on teaching science that enriched the content standards, particularly with increasing teachers' experiences with wet labs. Participating teachers delved deeper into the science content standards but also learned topics that are often skimmed or omitted from traditional teacher-based science courses, due in part to time constraints. Examples of content enriching topics taught included the examination and purpose of scientific modeling, e.g., conceptual and physical models and the use of different scientific models to study natural phenomena; and the effective use of STEM-based apps and tools (Suriel, 2021). Teachers were also exposed to local community and natural resources so that they could utilize them in their instruction. In every workshop, teachers learned about strategies to support language development for English language learners. During one workshop, an entire day was devoted to soil science. Instructional activities on soil science were designed to draw on students' knowledge and familiarity with soils for growing crops in these areas.

The goals with using these resources were to acquaint teachers with opportunities for enriching the curriculum and to draw from students' funds of knowledge. However, more could have been done to increase teachers' awareness of socially just practices. Though teachers were very likely aware of their students' everyday experiences because they themselves are natives of this region, in these workshops, teachers did not get to examine how science curricula can make use of students' funds of knowledge and use that knowledge as a starting point of discussion. This pedagogical strategy was not specifically addressed in the workshops because the first author was instructed to only address science content given that another teacher-instructor would address pedagogical strategies. However, discussions on the program revealed that an emphasis on social justice education was never conveyed by the teacher-instructors nor the directors of the program. In essence, participating teachers gained a deeper understanding of specific science content and learned some inclusive strategies to engage CLD and low-SES rural students, but teachers did not learn about social justice education and had limited exposure on designing instruction to meet needs of the CLD students, ELLs in particular, and to draw on students' funds of knowledge.

6.2.4 Two Educators' Ongoing Efforts and Practices to Support STEM Education

In our work, and considering limited STEM-based PD opportunities, the authors became acutely aware of the manifest need to provide STEM-based professional development. We are two female science and math educators, one of Latinx immigrant ethnic background, and the other of White background, working at the university and with rural school teachers serving high numbers of CLD and low-SES students. Both authors have experience teaching in public schools, one high school and the other elementary, and are current teacher educators and field supervisors. In this section, we provide some examples of our successes with STEM teaching our university students. We then discuss our challenges with seeking funding for STEM PD for our local teachers.

6.2.4.1 The STEMITL Project: An Enriching Opportunity for Multiple Stakeholders

To better prepare preservice teachers to teach STEM, the Science, Technology, Engineering and Mathematics Integrated Teaching and Learning (STEMITL) project was implemented, pre-COVID-19, with undergraduate middle level education seniors. The STEMITL project was conceptualized and directed by this chapter's first author, was carried out at the university's STEAM Center, and was funded internally by the university with a small grant of $30,000. Multiple stakeholders participated in this project including 5 different faculty members, 30 preservice student-teachers, and 430 culturally diverse, low-SES rural middle school students and their cooperating science teachers.

The faculty of the middle grades program collaborated with our student-teachers to codesign an interdisciplinary STEM-based curriculum focused on water pollution. Each design team was charged with creating lessons that integrated STEM and enhanced content knowledge within each discipline. The curriculum was taught by the student-teachers three times a semester for one year. They taught middle school students and asked them to: (a) examine social issues related to water pollution, (b) collect and analyze pH data of water from a local river to determine potential causes of water pollution, and (c) argue for social reforms that impact the health of water sources. Students use of technology was also an integral part of the curriculum and assisted student-teachers with instructional delivery but also with developing middle schoolers skills with use of various apps (e.g., data tabulating and analysis, creating visually enhanced texts, and communicating with other students across the globe). The STEM curriculum did not incorporate the "E" in STEM for designing technology to better assess and monitor water pollutants. However, discussions on environmental chemistry regarding industrial and farming chemicals that pollute local bodies of water were carried out. Such discussions were pertinent to students' lives in this context given the agrarian culture in this region. The faculty also thought it important to discuss ecofriendly behaviors and practices for protecting local water resources.

At the completion of the project, the student-teachers completed a survey about their experiences with the project. The 19-item survey consisted of 16 quantitative items and 3 qualitative items. Quantitative items' responses ranged from 1 to 5 on a Likert scale, with the highest score indicating the most positive response. Prominent findings from the survey indicated an increase in student-teachers' passion for teaching. For example, the highest ratings were for survey item 13 *This experience fueled my passion for teaching* ($N = 30$, $M = 4.57$, $SD = 0.72$) with 93% of students selecting a 4 or 5 as choice responses. Likewise, survey item 16 *This experience was a good way for me to improve my teaching techniques,* was also a high scoring item ($N = 30$, $M = 4.53$, $SD = 0.63$) with 93% of students selecting a 4 or 5 as choice responses. Another high-scoring survey item indicated that compared to White student teachers, Black student-teachers had more positive attitudes about their ability to apply integrated STEM curricula to different grade levels as a result of participating in this project. Descriptive statistics for this item show Black student-teachers' ($n = 9$) response Mean was 4.78 and Standard Deviation of 0.44 with 100% of students selecting a 4 or 5 as choice responses. Descriptive statistics for this item show White student-teachers' ($n = 20$) response Mean was 4.3 and Standard Deviation of 0.73 with 90% of students selecting a 4 or 5 as choice responses. One student did not identify their racial background, thus for this item their response was not evaluated.

Data gathered from qualitative survey items also indicated student-teachers' increased appreciation for experiencing STEMITL and for learning interdisciplinary strategies to teach it. For example, one student-teacher shared that "The most valuable thing…was getting to see the interdisciplinary curriculum… that is rare in the education system we have right now." Another student shared that "Until this experience, I too would have been guilty of not seeing that each subject can be connected…intertwined together as opposed to having each subject develop their own island of course content." Also, fieldnotes indicated that all participants, including faculty, were actively engaged in the conceptual understanding of water pollution as a socio-scientific issue. Interestingly, cooperating science teachers also learned from this experience and modeled parts or the entire project in their schools with their students. For more information on the STEMITL project, see Suriel et al., 2018.

The STEMITL curriculum benefitted local and rural low-SES and CLD students as they participated in a STEM-based enrichment opportunity. Their enthusiasm and excitement for learning showed in their facial expressions and demeanor throughout each STEMITL day. It was motivating to us, the faculty and the student-teachers, to offer a socially and academically just learning opportunity to our local students. Though funding for this project was limited, multiple stakeholders benefitted from this PD that was modeled with real students. With additional funding, this project could have gone further with incorporating more engineering practices, such as examining conceptual models or designing technology for monitoring water pollution or designing instruction that better defines social justice perspectives and approaches. Such approaches would have better modeled the integration of STEM and social justice education. Moreover, additional funding could help extend these experiences to future students, including elementary education students and teacher leaders. In doing so, the student-teacher population sample could be augmented providing us with opportunities for more rigorous data analysis (e.g., ANOVA) to detect any statistically significant differences relevant to this study.

6.2.4.2 Planning and Teaching Integrated STEM Lessons in the Mathematics Methods Courses

Elementary-level student teachers are often trained to integrate curricula. One advantage for elementary teachers is that they plan and teach lessons in multiple subjects such as science and mathematics, which helps them gain a better understanding of how these subjects relate (Bakirci & Karisan, 2018). However, effectively integrating STEM curricula may not be a required skill in their teacher education courses nor in PD (Banilower et al., 2018). To better assist elementary level teachers with integrating STEM curricula, the second author designs course activities that immerse students in the planning and teaching of integrated STEM. STEM integration in her course assignments include instruction that is student-directed and uses technology applications of mathematics and engineering practices.

One example of how students demonstrated integrated mathematics and student-directed technology use in a course assignment was when a student-teacher planned for her students to design animal pens for a farmer. For this activity, students were expected to use (a) science knowledge relating to animal needs for the size and shape of pens (relating to prior science lesson where they went on a free virtual field trip to a farm), (b) use free web-based virtual manipulatives to design and engineer their pens, and (c) mathematics to compare area and perimeter of the pens. In her reflection, the pre-service teacher noted that the students really enjoyed the activity because it was "more real to them than just solving problems on a worksheet." Many students noted in their reflections that they plan to teach more integrated STEM lessons in the future.

In another example of a graduate level course assignment, students were asked to showcase STEM integrated activities. One teacher had elementary students design "Leprechaun traps." For this activity, students were expected to use (a) virtual manipulatives to design their traps, (b) mathematics for measuring the dimensions of their geometric designs, (c) physics knowledge with designing moving parts, and (d) use engineering knowledge to build their traps using everyday objects from around their house (bottles, rubber bands, Legos, cardboard, etc.). Video submissions and teacher reflections for this assignment showed that not only did the students and teachers enjoy the integrated activity, but the young learners were engaged in higher-order thinking that supported a deeper understanding of the content. Teachers indicated in reflections that they intended to continue integrating STEM subjects. This course assignment shows that when provided with learning opportunities to integrate STEM, teachers can design and implement low budget but engaging STEM curriculum to support student learning.

These examples show that as teachers have opportunities to plan and implement STEM integrated lessons, even with limited funding, they can see the value of the lessons for student engagement and learning. One limitation of using university courses to improve STEM teacher education is that the population is limited to those teachers who are willing to pay tuition at the university. In order to create sustainable change, these same opportunities for STEM PD need to be expanded to local teachers who may not be able to afford university tuition.

6.2.5 Ongoing Initiative for STEM Education Professional Development with Inservice Teachers

The termination of funding for MSPs and current state budget cuts for PD motivated us to seek opportunities to provide continued STEM PD to local teachers. As such, we sought funding sources to sponsor this work. Drawing on what we learned from our colleagues who previously directed the MSPs, our intended goals for the year-long intermittent PD were to provide PCK enrichment regarding science, mathematics and technology, inclusive of computational digital literacy and social justice education. We targeted one group of same grade teachers working in the same school that served low-SES and CLD students. For the summer PD, we sought the participation from their school leaders. We also aimed to purchase digital devices for teachers to keep and use for instructional purposes, as suggested by Rodriguez and Morrison (2019). In the years that follow, we planned for the first-year teachers to train other teachers in their own schools. To gather evidence of teacher professional agency for enacting newly gained socially just STEM instructional approaches, we planned research using both qualitative and quantitative methods. In our design, we planned for connecting teacher effective instruction to student achievement and student motivation for learning STEM.

As the result of this agreement with the school principal for STEM targeted PD, we sought another source of funding to conduct the PD. We identified a grant funding opportunity offered through a renowned educational association targeting educational inequalities – made prominent by the COVID-19 pandemic. Again, we did not secure any funding for this PD when our grant proposal was declined. At this point amid the COVID-19 pandemic, all internal university-bound funding grants were suspended, further limiting funding opportunities. Although we continue to seek support from various funding sources to provide incentives for teachers to participate in the STEM-based PD, we may not be able to secure timely funding, and will be providing in-kind PD to support teachers' needs once pandemic restrictions ease.

6.3 Conclusion and Recommendations

Persistent educational inequities continue to plague the development of scientific literacy for low-SES and CLD learners. While many calls have been placed to address structural inequalities, these efforts have not affected the needed social change to transform STEM curricula that meets the needs of the low-SES and CLD students. Inadequate school funding makes evident the lack of commitment to these calls. In fact, public funding has decreased since the Great Recession of 2008 particularly for schools serving low-SES children (Black, 2019). Limited funding for STEM school programs and STEM-focused professional development has hampered ongoing efforts to effectively address and support teachers' knowledge gap on STEM and social justice education. In the state of Georgia, a lack of accountability measures for professional growth deteriorates the quality of curriculum students experience. This is a disheartening issue and unjust practice that places the most vulnerable learners at a competitive disadvantage for acquiring top-notch STEM education that can potentially transform their lives and future careers.

We presented the case of a regional Georgia state-funded Math and Science Partnership professional development that ran consecutively for 14 years. The goal of the MSP was to provide much needed STEM-focused PD, mainly science and mathematics, to rural and local science and science teachers near a small Southeastern city university nestled amidst produce and cotton farms. The well-funded MSPs were successful with their goals; however, demonstrably inconsequential as they failed to substantially evidence the enactment of the STEM approaches introduced. Moreover, the MSPs marginally focused on issues of socially just instruction. Part of the challenges discussed by one of the codirectors of the MSPs is keeping a balance in the enrollment of participants. To effect school change for the enactment of newly gained PCK resulting from the MSPs, she suggested targeting teachers from the same schools to maximize collaboration. However, she did not suggest how to best evaluate the efficacy of the PD regarding curricular implementation of learned approaches. Lastly, she suggested that PD administrators be intentional with training teachers about cultural diversity and modeling how to best teach it. Rodriguez and Morrison (2019) argue that the efficacy of any efforts for transformative change can be best addressed through narratives of engagement. That is, this approach seeks to balance a discussion of the "challenges and successes encountered with teaching and learning in culturally diverse contexts and of the responsive (and responsible) role of the researchers in bringing about social change" (p. 278).

The coauthors of this chapter also showed how they sought to address and increase STEM PCK in student teachers. The first author showcased a low-budget STEM project that benefitted multiple stakeholders. This project's research findings illustrate that teachers' ingenuity for effective instruction can be supported through concerted efforts from socially just and critical friends. However, financial support for the many educators (faculty, staff, student teachers, and cooperating science teachers) who carried this project over many days was minimal or altogether missing. It is this kind of work that needs financial compensation to sustain more equitable practices and experiences for CLD student teachers and their future CLD students.

Lastly, we shared our experiences seeking grant funding to finance STEM-focused professional development. We considered lessons learned from our colleagues to design effective PD and adhered to the recommendations made by Rodriguez and Morrison (2019) for researcher practices with connecting PD efficacy to sociotransformative change. As such, our grant proposals specified research methodology to include both quantitative measures to expediently analyze data connecting teacher implementation of PD practices to student achievement, and qualitative measures to document the roles of teachers and researchers in bringing positive social change. Unfortunately, after seeking grant funding on two different occasions, our grant proposals were declined. However, we persist in our efforts to provide much needed STEM PD to our local teachers, especially because of recent state budget cuts for PD and lack of accountability for professional growth.

Collectively, our stories highlight the need for funding STEM-based, socially just PD and increased PD accountability measures for professional growth in teachers. We brought awareness to different challenges posed to public education and research in low-SES and rural school contexts. We conclude by offering one more consideration aimed at public and private grant funders. Large geographical distances between schools and students and teachers are not often accounted for when considering adequate funding. Teachers and students may not only be socially disconnected but also physically isolated from meaningful diverse cultural interchange. While social media may provide a forum for cultural interactions, intermittent digital connectivity presents an additional barrier. Thus, it is important that funding sources consider these additional challenges if we aim to enact more socially just practices for rural, low-SES and CLD students.

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Chapter 7
Exposing the Invisibility of Marginalized Groups in Costa Rica and Promoting Pre-service Science Teachers' Critical Positional Praxis

Alberto J. Rodriguez and Marianela Navarro-Camacho

7.1 The Costa Rican Context

Dr. Rodriguez (the first author) visited Costa Rica (CR) during his sabbatical in order to explore possible research collaborations. He has previously visited CR and has always been fascinated by the abundant natural beauty of this country and by its citizens' widespread environmental sustainability consciousness. While this may not be the case for every person, Costa Ricans continue to gain admiration abroad for their deep commitment to green energy and for seeking to preserve their country's natural beauty. Almost everywhere you go, recycling is part of the culture, and the CR government continues to make bold moves toward green and sustainable energy. For example, most of CR's electricity needs are met through renewable resources (78.26% hydroelectric; 10.29% wind energy; 10.23% geothermal, and about 0.83% solar and biomass) (Reve, 2020). In addition, the current government has pledged to reach zero carbon emissions by 2050 (CR Government, 2021).

As part of the CR's government ambitious agenda is the recognition that in order to accomplish (and sustain) the country's green energy and economic growth goals, a well-educated citizenry is required. To this end, the Ministry of Education introduced a new set of education standards, *Educar Para Una Nueva Ciudadania* (Education for a New Citizenry, Ministry of Education, 2017). These standards call for the promotion of students' understanding of sustainable development; cultural

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diversity; critical thinking and creativity; solving real-world problems; collaboration; and global/local citizenship. In fact, there are many similarities between the new Costa Rican (CR) education standards and the US Next Generation Science Education Standards (NGSS, Achieve, 2013). In addition, both countries recognize two major obstacles for achieving their desired goals are: (1) The lack of participation of women and other underrepresented groups in STEM-related fields and (2) The limited opportunities available for teacher professional development in relation to the new standards.

We know that lower achievement and participation in STEM is a persistent trend that starts early in elementary school and this gap broadens through high school and beyond. For example, in the latest results of the Program for International Student Assessment (PISA) (OECD, 2018), CR's 15 years old scored an average of 402 points on the mathematics test, while the Organization for Economic Cooperation and Development (OECD) countries' average score was 489. CR's boys attained 18 points higher score than girls in mathematics and 9 points higher in science. Research studies in the US indicate that the difference in scores between boys and girls do not have anything to do with ability but with the curriculum and sociocultural interactions in the classroom (Rodriguez, 2004, 2015a; Zozakiewicz & Rodriguez, 2007). To put it bluntly, girls, young women and other underrepresented students in STEM simply find the traditional teacher-centered and decontextualized curriculum boring and disconnected to their everyday lives. Here is where the CR's new education standards could play a key role in helping turn this trend around in both the US and CR:

> An education for a global citizen requires that students take an active role, to confront local and global challenges and contribute to a much more just, peaceful, secure, inclusive and sustainable world for all (Education for a New Citizenry, Ministry of Education, 2017).

While this an excellent educational goal, as mentioned earlier, one of the major obstacles obstructing its progress is the lack of effective professional development for teachers. In other words, we know that teachers in both countries—especially high school science teachers—continue to be mainly trained using traditional and canonical approaches to teaching and learning (Alfaro Varela & Villegas, 2010; Navarro-Camacho, 2019). No national survey on teachers' perceptions of their ability to teach STEM-related subjects has been conducted in CR, but in the US, the most recent National Survey of Science and Mathematics Education Report (Banilower et al., 2018) showed that 31% of teachers feel very well prepared to teach science and only 3% feel very well prepared to teach engineering.

It is evident that in order to increase the participation of women and other marginalized groups in STEM, a more systemic approach is needed. Furthermore, several scholars (including the authors) have demonstrated that helping teachers integrate culturally inclusive pedagogy with inquiry-based, hands-on, and minds-on STEM practices is an effective approach for making a long-lasting and significant impact on student achievement, as well as promoting students' interest in STEM-related careers (NRC, 2012; Rodriguez, 2015a; Rodriguez & Morrison, 2019).

Given the high interest in both the United Staes (US) and CR to address common educational goals, and given that both countries were seeking to implement new science education standards, we (co-authors) agreed to implement and expand a mixed methods research project based on a current longitudinal study the first author is conducting in the US. Before we share more details about this project and its findings, we would like to first describe some of the challenges and successes we encountered while seeking funding. One of our goals with this chapter is to encourage university administrators and funding agencies to be more supportive of international research collaborations and recognize the potential for advancing scholarship and common educational and equity goals.

7.2 Seeking Funding: Challenges and Perseverance

In contrast to the impulse for STEM education in the US, CR is promoting STEAM (science, technology, engineering, arts and mathematics) education. However, there are no plans for government-sponsored and systematic teacher professional development, nor for providing schools with the necessary equipment and materials to integrate engineering practices. In short, this is a very similar situation to that found in the US (Rodriguez, 2015b). Since the first author's US-based project mentioned above had a focus on addressing equity, diversity and social justice issues through cross-cultural STEM education, we developed a research proposal to support the implementation and expansion of this project in Dr. Navarro's science methods courses for secondary science teachers. In addition, Dr. Navarro—who is also the Coordinator for the Secondary Science Teacher Education Program at the University of Costa Rica (UCR)—was leading major reform efforts in her program. Therefore, she and her colleagues were excited about our collaboration because their students have not been previously exposed to any professional preparation in STEM/STEAM education or in cross-cultural education. Yet, as mentioned above, the new CR's standards were expecting teachers to be proficient in both areas.

We submitted a research proposal to the UCR's Instituto de Investigación en Educación (Institute of Education Research–INIE) and we obtained enough funding to secure the equivalent of one course release for Dr. Navarro and for hiring a part-time student assistant. This was a significant achievement because funding to support this kind of projects in education is very difficult to obtain at the UCR. In addition, program coordinators at the UCR have significant teaching loads and are often burdened with additional administrative duties—much more than what we encounter in equivalent R1 universities in the US.

Everything was going well, so we were excited about seeking support from Purdue University–the first author's former home institution; after all, Purdue has one of the largest international student populations in the country due to its strong engineering and science programs. In addition, no other faculty from the college of education had an active international research project collaboration with pre-service teachers at the time. Unfortunately, this excitement was short-lived. In fact, sometimes nothing seems to murder the joy of pursuing an innovative scholarly endeavor more abruptly than discussing such endeavor with a desk-bound university administrator. Instead of celebrating the potential for cultural exchange and scholarship that this project offered, I was swiftly steered to talk to others to ensure that the university's "interests" were protected. When I explained once again that this was a seed project with no material cost to the university, I was given a long form to fill out before our project could be "processed." This is one of the questions from the university's *Sponsored Programs Office*:

> Describe the number and also the nature/intent of previous and/or current agreements or relationships with this institution/entity. Please also describe Purdue agreements with other institution/entities within the same country. Please use this global-linkages database to search.

My response to this question did not hide my frustration:

> This is a ridiculous question. How does this have anything to do with the partnership I'm trying to establish? Why should I be expected to research other agreements between Purdue and other institutions within this country when seeking to establish this one is difficult enough!

This situation was aggravated by our request to have a university official sign a memorandum of understanding produced by the UCR describing the scope of work and responsibilities of the researchers. This was really meant to be more of a formality and a courtesy to keep everyone informed, and the document made it clear that nothing material or financial was expected from my home university. After multiple e-mails repeating the same arguments to multiple people who could not see beyond established forms and archaic procedures, we secured a revised memorandum of understanding from the UCR that just accepted the first author's signature. This enabled us to move the project forward.

Because it became evident that no support was forthcoming to advance our project, we turned our gaze elsewhere in order to secure additional funding. We were surprised and dismayed by the dearth of funding opportunities for international research collaborations like ours. It seems that where funding was available, it was targeted for countries in extreme needs or for developed European countries. Developing countries with a strong democratic history and a commitment to global peace and environmental sustainability do not seem to attract the attention of funding agencies. A short-sighted fact considering how much we could learn from CR—a country that abolished its standing army in 1948 and reallocated those funds to improve public education and health. In addition, CR has one of the most stable democracies in Latin America.

We found out that the Fulbright Scholar Program was about the only option we could pursue, and Dr. Rodriguez applied and eventually received this award. Purdue University does provide support to faculty interested in applying to this program because it is used as an indicator for university rankings, and because this institution was interested in improving its record of faculty receiving these international grants compared to other R1 universities across the US. In any case, we were grateful regardless of whatever the institutional motivation was, but we could not help lamenting once again that intellectual curiosity, moving beyond ethnocentric understandings of teacher professional preparation, promoting equity and social justice, and so on, were not the driving forces for supporting international collaborations. This realization accentuates even more how essential and unique the Fulbright Scholars Program truly is for promoting international collaboration and cross-cultural understanding (https://cies.org).

7.3 Sociotransformative Constructivism and Critical Cross-Cultural Education

The Fulbright grant enabled us to make our project longitudinal; that is, we were able to work with the same cohort of secondary pre-service science teachers through the three consecutive science methods courses (over three semesters) required by the UCR teacher preparation program. We will describe more details about the teacher education program in the next section. Here, we wish to briefly describe the theoretical framework guiding our project.

Our study is informed by *sociotransformative constructivism* (sTc)—a framework that merges critical cross-cultural education (as a theory of social justice) with social constructivism (as a theory of learning) (Rodriguez, 2011/1998). Therefore, we are in agreement with Lev Vygotsky's (1978) conceptualization of learning as a social activity dependent on the context and experiences of participants. This implies that an individual's language (in whatever form and including symbolic language), culture, and experiences mediate what and how that person learns during social interactions with others. In our view, if we believe that learning is influenced by the participants' prior experiences and social interactions, then the construct of power must be considered as one of the key mediating factors. This is where sTc serves as a bridge between social constructivism and critical cross-cultural education because the individuals' positionalities determine their access to (and influence upon) the culture of power. For example, a female, dark skin Latina, physics teacher teaching advanced high school physics courses with a focus on gender equity in STEM in predominantly Anglo, male high school classrooms might experience different power dynamics than an Anglo male counterpart. Thus, sTc raises awareness about how an individual's multiple positionalities—be it ideological, socioeconomic, academic, ability status, sexual expression, skin color, etc.— might influence their, his or her access to power, and how power mediates teaching and learning interactions.

This critical lens for understanding social constructivism is congruent with critical approaches to multiculturalism (May & Sleeter, 2010). In other words, sTc rejects neoliberal notions of multicultural education focused on "acceptance," "tolerance," "diversity," "awareness," and superficial understandings of "equality." Instead, sTc promotes critical cross-cultural understandings of not only how webs of oppression obstruct access to meaningful education for everyone, but it also promotes the dismantling of the systemic roots that sustain those webs of oppression.

To this end, sTc is composed of four interconnected elements: *the dialogic conversation, authentic activity, metacognition, and reflexivity* (Rodriguez, 2011/1998). These constructs are not "stages," or "phases," nor any kind of traditional (Western) linear thinking ensemble. They are simply conceptual devices meant to facilitate teaching and learning for transformative action through culturally and socially relevant pedagogical strategies and curriculum. Thus, any one or more of these four elements can be enacted at any time in response to the challenges and opportunities typically found in school contexts. (For more information on how sTc has been deployed in various learning contexts see: Morales-Doyle, 2017; Rodriguez, 2015a, 2021; Tolbert et al., 2018).

While we enacted all four elements of sTc in our project, for this chapter, we focus on *reflexivity* and the *dialogic conversation* since these are most relevant for discussing teacher identity development in our research context. The dialogic conversation is primarily based on Mikhail Bakhtin's (1986) construct of *dialogicality*. This construct enables us to better understand the complex process of meaning-making among individuals because it problematizes taken-for-granted assumptions about listening and speaking or 'just engaging in dialog.' For example, in educational research, it is common to hear about the importance of promoting: students' collaboratively work in groups, the open discussion of their findings, and the development of their scientific-argumentation-from-evidence skills, and so on. However, this approach assumes that all that is needed is for teachers to organize students in small groups, and then complex meaning making will just happen. We believe this process is much more complicated. Using Bakhtin's dialogicality construct, we argue that teachers and students also need to understand how their identities or multiple positionalities (i.e., ethnicity, gender expression, sex, experiences, language abilities) influence what and how they think. In short, a dialogic conversation does not involve just listening, reading or deciphering words or symbolic language, it involves understanding how the speaker's and the listener's voices harmonize (construct meaning together) or collide (creating tension and dissonance). This is where sTc advances the notion of dialogicality by directly addressing issues of power. In other words, teachers (with their privileged, authoritative voices) are perfectly poised to guide and encourage dialogic conversations through which students (and their teachers) engage in meaningful and respectful conversations. In these dialogic conversations participants are not just hearing words, they are listening and paying attention to what is being said, as well as who the speaker is (i.e., the speaker's positionalities). For the dialogic conversation to work effectively, additional efforts are needed to ensure that everyone in the dialogic context (e.g., classroom community) knows one another well and are interested in building trust and respect for each other.

We argue that for teachers to be able to promote dialogic conversations in their classrooms, they also need to have a strong sense of their own identity (or multiple positionalities), and in our view, identity and *reflexivity* are closely linked and always influenced by one another. Thus, for sTc, reflexivity involves engaging in an on-going process of critical self-reflection on how one's own multiple positionalities determine one's actions (or inactions) (Rodriguez, 2011/1998, 2015a). In order to better distinguish between espoused beliefs (good intentions/heightened awareness) and beliefs in action, we prefer to use the term *critical positional praxis (CPP)*. That is, CPP is the enactment and public manifestation of our sense identity; how we perceive other people's identities; and of the meanings produced by those interactions. Thus, this approach adds a transformative action component to Crenshaw's (1991) notion of intersectionality. That is, Crenshaw articulates that our identities are never singular, but multiple and determined by various sociocultural positions (i.e., gender expression, socioeconomic status, education, sex, physical ability, ethnicity, language abilities). However, what do we do with increasing one's self-awareness? How does this translate into actions that impact our everyday lives, as well the lives of others around us? We suggest that CPP answers these questions. For example, a strong sense of identity (or of our multiple positionalities) might provide us with the resilience and determination to pursue our goals. However, if others, who are in higher power positions, perceive us as incapable and unworthy due to their perceptions of who we are, they will unfairly make our goals so much harder to achieve. Thus, CPP provides the toolkit to recognize that our identity is not only defined by who we think we are, but by how others construct representations of our identities based on those individuals' understanding (or lack thereof) of their own identity

This relationship between our own sense of identity and how we are constructed by others plays a significant role in our personal, psychological, educational, and professional growth. Therefore, CPP enables us to take action by ensuring that others perceive us as I we would like to be identified (e.g., Latina not Hispanic; or gay not heterosexual; or multilingual not someone with an accent; physically able not disabled because of hearing challenges; or professor not international graduate student; and so on). Similarly, CPP enables us to be more mindful (through reflexivity) about how we construct other peoples' identities and how we interact with them based on those perceptions. In short, the difference among reflexivity, identity and CPP is that while all of these constructs are interlinked and influenced by one another, reflexivity and identity configure and provide meaning to a present version of ourselves in a given time and context. Thus, reflexivity and identity are primarily private processes occurring in our minds. Whereas CPP, on the other hand, is the public manifestation of the insights gained through our sense of identity and reflexivity; in fact, CPP are actions (on inactions) that express who we are.

For our project, we sought to assist pre-service teachers in their identity development through reflexivity, and to promote their CPP through their collaborative work, lesson planning and teaching. We are aware that much has been written on teacher identity in various fields of inquiry (Jupp et al., 2019), and that the construct of teacher identity has gained more interest in science education in recent years (Avraamidou, 2014). Elsewhere, Rodriguez, Tolbert and Mark (in press) address some of the issues associated with the current research on science teacher identity development, such as the modest analyses of this construct in relation to issues of power dynamics, systemic racism and other forms of oppression.

While a comprehensive critique of the literature on the construct of identity is not the focus of this chapter, we sought to articulate how we theorize the interactions among identity, reflexivity, and critical positional praxis in our efforts to support the participant pre-service teachers' professional development as culturally responsive teachers. We also explained that one of the primary means through which we sought to facilitate all of these processes is through dialogic conversations with the participants. In the next sections, we share highlights from our research findings that more specifically illustrate how the sTc elements of reflexivity and the dialogic conversation were enacted to promote the pre-service to teachers identity development and critical positional praxis.

7.4 Methodology

7.4.1 The Costa Rican Secondary Science Teacher Preparation Program

As mentioned earlier, we follow the same cohort of secondary pre-service teachers (PSTs) through three required science methods courses: *Methodology in the Teaching of Sciences* (which is similar to the typical science methods courses taught in the US with an emphasis on pedagogy and developing curriculum). *Teaching Experience in Sciences* is like an extended science methods course that also includes their school-based teaching placements. The third course, *Seminar in the Teaching of Sciences*, involves PSTs learning about research methodologies and conducting a small research project in school-based placements. This is a very unique approach. In the US, PSTs typically have only one science methods course, and they do not have a methods course associated with their final school-based placements. The latter usually represents the last semester of PSTs teacher preparation in the US. However, the UCR's teacher education program requires PSTs to take a research methods course that aims to enhance PSTs' understanding of science pedagogy, curriculum and theory in various school contexts. Interestingly, teacher graduates often continue their studies and pursue a *lincenciatura* or licentiate degree for two additional years. This additional certification enables them to secure a higher remuneration and status when assigned a teaching position (in Costa Rica the assignment of teaching jobs at public schools is centralized and administered by the Ministry of Education). PSTs also have the option to pursue other graduate degrees, such as a master's or (with less frequency) doctoral degrees. Important to note is that none of the Costa Rican universities offer doctoral degree with specialization in science education.

7.4.2 Participants

Our project included 17 secondary pre-service science teachers. Nine of them are women (52.9%), seven are men (41.2%), and one is Other (5.9%). Ethnic identity is a key construct being investigated in this study, so we address it in more detail in the next sections. However, at this juncture, it is important to note that 14 PSTs identify themselves as Mestizos/as (82.4%); two as Mulatos/as (0.12%) and one as Other (0.06%). The first author is a Latino (male), and the second author is Mestiza (female).

7.4.3 Research Tools and Analysis

We used a variety of quantitative and qualitative research tools that included pre-post surveys. In addition to the general demographics questions, the survey included questions about whether the participants have ever experienced any form of discrimination based on gender, skin color, sexual orientation, socioeconomic status, or other factors. We also sought to monitor changes in the pre-service teachers' self-efficacy. That is, we used a Likert scale and short answers questions (Plowright, 2011) for participants to share their perceptions of preparedness to integrate STEAM and cross-cultural education in their science teaching practice. We also sought to evaluate any changes in their perceptions of preparedness to teach in any of the core science areas biology, physics, geology and chemistry. In CR, secondady teachers are certified to teach all of the science courses. The pre-survey was administered at the beginning of the first course, and a post-survey was administered at the end of each of the three methods courses to monitor knowledge growth and changes in the PSTs experiences. Same gender focus group interviews (4 females and 4 males) were conducted at the end of each methods course, and we also gathered data from teaching observations, review of artifacts (lesson plans and students' class work), and field notes. For this chapter, we are primarily drawing insights from the ethnographic analysis of the pre-post surveys data, short answers, and focus group interviews (Spradley, 1979); therefore, we are not sharing here a full analysis of the quantitative and qualitative data we gathered over the course of three semestes. Our goal is to provide a critical auto-ethnographic analysis of how our collective understanding was impacted as issues regarding notions of ethnic/cultural identity arose through our dialogic conversations with each other and with the PSTs. Critical auto-ethnography (Marx et al., 2017) is a methodological approach well-suited for this reflexive re-telling of our encounters with dominant discursive practices (from the US and CR), and how the insights gained helped guide our study.

7.5 Findings

Overall, preliminary analysis of the quantitative and qualitative data shows significant gains in the PSTs perceptions of their abilities to integrate cross-cultural and STEAM education in their practice. However, for this chapter, we focus on insights gathered on ethnic/cultural identity development and its potential impact on future teachers' abilities to establish the kind of culturally inclusive and socially relevant science/STEAM classrooms everyone expects them to create. Thus, we begin by explaining how two elements of sTc—the dialogic conversation and reflexivity—guided these insights.

7.5.1 The Dialogic Conversation and Reflexivity in Action

Because this project is an extension of an ongoing research being conducted by the first author, we asked participants to disclose their ethnic identity associations as it is a common practice in the US. Interestingly, this presumed to be 'common' question in the US context stirred unexpected reactions and long discussions, which in turn inspired the writing of this chapter. Originally, the first author (Dr. Rodriguez) sought to include the same open-ended questions he uses in the US context in order to explore how pre-service teachers (PSTs) would identify themselves without having to be constrained by the typical pre-designated ethnic/cultural (racial) boxes one often finds in surveys. In addition, since Dr. Rodriguez identifies as Latino (originally from South America), as an immigrant citizen of the United States and Canada, and as an English and multilingual learner, traditional ethnic identity questions often feel awkward and stuck in colonial framings. That is, these questions tend to focus more on superficial shades of skin color and 'racial' labelling instead of celebrating individuals' rich ethnic and cultural roots (Rodriguez, 2004, 2015c). Therefore, he suggested to ask the Costa Rican (CR) participating pre-service teachers the open-ended question: *What ethnic/cultural group(s) do you identify with?* In the US context, the answer to this question is very useful for guiding PSTs in the exploration of their own ethnic identity as future teachers who will most likely be working with very different cultural groups than their own. Similarly, Dr. Rodriguez sought to explore the CR participants' ethnic identity positionalities. However, Dr. Navarro (the second author) indicated:

> Here we would not know what to answer, and there are no indigenous students in our program. In addition, if we write down Caucasian, Afro-descendant or Indigenous, we all have those genes, we do not consider ourselves Caucasian, but Creole (Criollos) or Mestizo (Field notes, Year I).

Dr. Navarro, who identifies as Mestiza, and born in Costa Rica, raised this interesting point. Our research assistant, who also identifies herself as a CR Mestiza, agreed. They suggested to drop this question altogether from the survey because it would cause confusion. We decided to exclude the ethnicity question, but the

Table 7.1 Responses to the survey question: *Have you had any experience in which you have felt discriminated against because of your: [choose the relevant answer (s)]*

Category	Number of respondents	Percentage of respondents
Gender?	5	35.71%
Sexual orientation?	1	7.14%
Skin color/ethnicity?	0	0.00%
Socioeconomic status?	4	28.57%
Other?	4	28.57%

Latino-US centric framing of the question caused us to continue a dialogic conversation as we were all surprisingly puzzled by each other's reaction to it.

One related question that we did keep in the survey was: *Have you had any experience in which you have felt discriminated against because of your: [choose the relevant answer (s)]: a. gender; b. sexual orientation; c. skin color/ethnicity; d. socioeconomic status; e. other*. Table 7.1 summarizes the responses (Most but not all 17 participants answered this question). As it can be observed, the pre-service teachers, who were mostly women (53%), had direct experience with sexism, one participant explained:

> Some people think that women are not capable enough to develop in scientific fields and that is why I have heard comments from people who say that women should not teach science because they do not know the same as a man. (Pre-survey I, short answer questions)

Another participant illustrates the multiple discrimination one often encounters while inhabiting multiple intersectionalities:

> I am from a small town and people believe that women should just have children and not dedicate their lives to just studying, also throughout my life I have experienced discrimination for not having luxury clothes or the fashionable cell phone even here at this university it has happened to me. (Pre-survey I, short answer questions).

Almost a third of the participants (28.6%) explained that they have experienced discrimination based on their socioeconomic status. Interestingly, however, no participant indicated that they have been discriminated based on their skin color/ethnicity. However, racism unfortunately continues to be a very significant oppressive factor for Black, AfroLatinos(as), and Indigenous peoples in Costa Rica and elsewhere (INEC, 2011; United Nations, 2013).

The absence of comments regarding racial discrimination and the apparent longstanding lack of pre-service teachers from African and Indigenous cultural backgrounds enrolled in the University of Costa Rica's (UCR) teacher education program re-triggered the research team's dialogic conversation about whether to ask participants to disclose their ethnic/cultural associations. We decided to pursue this additional question, and just the process of doing so, as well as the participants' responses triggered transformative dialogs for all of us (researchers and pre-service teachers).

First, as we discussed what would be appropriate ethnic/cultural categories to include in our ethnicity question for the participants, it was striking to observe the similarities in the use of colonial and color-coded discourse between the US and CR

Table 7.2 Costa Rican official ethnic categories[a]

Ethnic category	Definition
Black or Afro-descendant	People who mainly recognize in their identity the cultural roots of African descent and their diaspora.
Mulatto(a):	The people who recognize mainly in its identity the roots cultures of African descent and their diaspora from one of his parents.
Chinese	People with ancestry from the People's Republic of China, including Taiwan and Hong Kong. Does not include people of other Asian ancestry.
White or Mestizo(a)	People who mainly identify with the legacy of Hispanic American culture and history. This also includes people who identify with the legacy of European or Anglo-Saxon culture and history.
Indigenous	Any person identifying as a member of one or more of the various indigenous ethnic groups of Costa Rica. (These are explained in more detail in the next section).
Other	People who self-identify with any ethnic group not mentioned in the previous categories.

[a]Categories translated directly from those indicated in the INEC, 2010 (Census Taker Manual, p. 142)

(see Table 7.2). In other words, according to the CR National Institute of Statistics and Census (INEC, 2010) colonial terms such as, Mulatto, Black, and White endure.

For Dr. Rodriguez, who identifies as a Latino, and who has consistently refused to use colonial, color-based ethnic categories in spoken or written forms (Rodriguez, 2004, 2015c), the discovery of this differentiation by CR national census was astonishing in two significant ways. First of all, it provoked critical reflection on ethno-US centric notions of what it means to be Latino once again. In other words, as a dark-skinned Latino, he first experienced racial discrimination as an international student in Canada and became aware that a different shade of skin color can make a person an object of hate. This experience reshaped his Latino identity to this day. Unfortunately, even decades later, and as a full professor, he continues to experience racism in and out of academic contexts. In addition, after working at various universities in the US, he has become more aware of the rich diversity within the US Latino/a community (e.g., Chicanos/as, Hispanic, Latinx, Mexican Americans, Caribbean Latinos, Puerto Ricans, Dominicans, AfroLatinos/s, Latino/a, and more). However, the official differentiation in CR of Afro-Latinos as Mulattos/as or Afro-descendants/Black, and the confluence of White with Mestizo/a (Table 7.2) further problematizes the established demographics designations in the US and taken for granted notions of what it means to be Latino/a. This is particularly important for teachers to consider when working with students in culturally and linguistically diverse contexts. Second, for Dr. Navarro, our dialogic conversation on this issue provoked her to reflect on the persistent absence of Indigenous and Afro-descendant students in her teacher education program since the ethnicities of pre-service teachers enrolled in her program have not been monitored. This also caused us to wonder what policies (if any) were in place by the College of Education and UCR in general to recruit and retain students from marginalized backgrounds (we share findings on this issue in the next section).

After asking the participating pre-service teachers to share their chosen ethnic/cultural identity using the official CR census categories (see Table 7.2), it was fascinating to observe the productive dialogic conversations that it caused. Again, because this project is guided by sTc, these are the kind of critical and reflexive discussions that the dialogic conversation and reflexivity promotes. These findings are best represented in the participants' responses during the focus group interviews (pseudonyms are used throughout):

> I had a problem with the ambiguity because in the option of White, it also said Mestizo; that is, I do not consider myself White because I am Latino, let's say but I wanted to mark Mestizo, so I wanted to mark both (Luis, FG I, p. 4).

Other students in the same focus group expressed similar hesitation and confusion, "I was also confused because I didn't know how to classify myself in relation to the categories in the survey, so I chose Mestizo" (Pedro, FG I, p. 4). Another dark-skin student did not find a category that best represented him, so he chose Mestizo as he understood this category more a mixing of multiple ethnicities, he adds:

> I have a great grandmother who is from China from my father's side, and from my mother's side I have a great grandmother who is from Germany, so for me it is more the mixing of everything (Javier, FG I, p. 4).

We conducted separate focus group interviews by gender in order to explore any possible gender-based issues across the project. However, in regard to this question, we found the same level of ambiguity and hesitation among the female students. For example, Veronica explains:

> I believe that the classification made by the INEC (the census institute) is not the one with which I feel most identified, because there is no specific classification with which I identify myself, which is between Mulatta and Mestiza. . . in our education program, they do not teach us how to identify with something specific. We know that we are a mixture and I think that knowing that we are a mixture, we do not identify with something specifically. I think that because of social networks and because of the information bombshell, I think that being Latino is very important first and I think that is what most people classify into, but between Mulatto and Mestizo, taking into account that we have more part, let's say, of America than from the other continent but I do not feel that it is an accurate classification (Veronica, FG I, p. 3).

Carmen, another participant, agreed with Veronica, and expressed a common reaction among students, "It is curious because until you asked me this question, no one had asked me, I had never thought about it, I have always considered myself a mixture of everything and very similar on what Veronica said, it would be like a Mestiza, is what I, through the education I have received over the years, is the word I find to describe myself according to that (Carmen, FG I, p. 3). Another student, Maria, expressed less hesitation,

> Well, I think that regarding this question I have had no doubt that I classify myself as Mestiza, I have always had that very present, and there is even a curious story in my family where there is a great-great-grandmother who was completely an Indigenous person. . . That's why I have that certainty that there is Indigenous blood in my veins, so I qualify myself as Mestiza (Maria, FG I, p. 4).

It is important to note that all three of these students, based on their physical appearance, would be perceived as White in the US or in Costa Rica, but their chosen identities are Mestizas. These findings further demonstrate the complexity of better understanding our own ethnic/cultural identities, as well as how these understandings are influenced by how others perceive us. Thus, our identities are not determined by government-designated fixed categories, nor by other people's perceptions of which possible category might make them feel less threatened or comforted in our presence, our identities are ultimately embodied by the steps we take to help others see us through our eyes. To accomplish this, we must first develop a strong sense of critical positional praxis (CPP), and as educators, this is an essential first step in becoming an inclusive and responsive teacher. This is also congruent with current education reform efforts in both CR as well as in the US. That is, as mentioned earlier, science teachers are expected to promote critical thinking to address real world problems, cultural understanding, sustainability, and global citizenship (Education for a New Citizenry, Ministry of Education, 2017; NRC, 2012). However, we argue that to promote cultural understanding and global citizenship, teachers must have a well-grounded and critical understanding of their own ethnic/cultural identities.

Now, given that participants (just like PSTs in the US) expressed that they had very limited exposure to university courses with a focus on cross-cultural education, and much less on the critical integration equity, diversity and social justice issues in science/STEAM, we took steps to engage them multiple activities throughout the project that did just that. For an example of a complete activity that also modeled how to integrate a culturally responsive and responsible engineering design process see Rodriguez (2021). In addition, we used insights from the aforementioned findings to assist students make relevant connections between the contributions of Indigenous and Afro-descendants individuals to STEAM. We also continued to encourage reflection on their own ethnic/cultural identities as future teachers who would most likely be placed in spaces where such a diversity will be present. In Costa Rica, graduates of the teacher education programs are assigned to available teaching posts around the country. This means that some postings could be in rural communities with higher number of Indigenous students, or in more populated areas with a higher population of Afro-descendants.

While our project is on-going, preliminary quantitative and qualitative data analysis continue to show significant growth in the pre-service teachers' perceptions of their ability to integrate critical cross-cultural and STEAM education. Participants also indicate that they find integrating equity, diversity and social justice issues the most challenging since this is the first time they are exposed to this approach. This concern is the same as that expressed by pre-service teachers in the research literature due to their similar prior academic preparation in science as canonical, Western and decontextualized (Navarro-Camacho, 2019; NRC, 2012; Rodriguez, 2015a). Nevertheless, we are excited to observe that all PSTs were consistently making progress in their efforts to enact their CPP by more purposely making connections between equity issues and their students' everyday lives. Similarly, the PSTs were also seeking to integrate the contribution of traditionally underrepresented ethnic groups to science/STEAM.

7.5.2 The Costa Rican Sociocultural Context and the Invisibility of Marginalized Groups

As we became more intrigued by our findings regarding the participants' conceptions of their ethnic/cultural identities, we also wondered about what, if any, policies the UCR College of Education and the UCR had in general to monitor, recruit and retain students from traditionally marginalized cultural backgrounds. After all, one of the principal goals of the UCR for 2021–2025 quinquennial is to "strengthen the institutional strategies that favor and promote equity in the admission process" in order to "promote affirmative actions that favor equity in the admission of traditionally excluded and vulnerable populations" [Políticas Institucionales 2021–2021, Eje III Cobertura y Equidad, política 3.1]. In this section, we share what we discovered and the actions we took to support transformative change (critical positional praxis).

Once we identified the official ethnic categories used by the CR census institute, before posing the ethnic/cultural identity question to participating pre-service teachers, we wanted to make sure to use the same categories deployed by the UCR. We contacted the Vice-Provost Office for Student Life (Vicerrectoría de Vida Estudiantil), and we were surprised to learn that the UCR *does not* consistently monitor ethnic categories because this information is considered "sensitive." After several attempts, an official shared that in the academic year of 2015–2016, the number of Indigenous students was 98. No other enrollment information was available for this ethnic group for other academic years. Considering the aforementioned mission of the university to provide educational opportunities to all members of society, this policy essentially renders invisible the most vulnerable and marginalized ethnic groups in the country. Furthermore, this policy also contradicts the aforementioned national education reform efforts that call for the increase in participation and success of traditionally underrepresented groups in science and engineering. It is well established in the literature that this type of invisibility increases rather than reduces discrimination, because it prevents rigorous and consistent analysis that allows informed decision-making based on data. (Rodriguez, 1999; Rodríguez & Mallo, 2012).

We wondered if other major public universities were also implementing a similar invisibility policy. Table 7.3 shows that all other universities invisibilize Afro-descendant students, with the exception of the National University. While the UCR appears to be the only one who invisibilizes both Indigenous and Afro-descendant students. All the other universities monitor the enrollment of Indigenous students, and the distance learning university (UNED) has a special program to support indigenous students, who often reside in very remote areas.

Table 7.3 Number of newly admitted Indigenous and Afro-descendant students in the country's public universities, school year 2019

Ethnic Category	University of Costa Rica (UCR)/ Universidad de Costa Rica	National University (UNA)/ Universidad Nacional	Technology Institute of Costa Rica (TEC)/ Tecnológico de Costa Rica	State Distance Learning University (UNED)/ Universidad Estatal a Distancia	National Technical University (UTN)/ Universidad Técnica Nacional
Indigenous	98[a]	54	34	698	11
Afro-descendant	No informacion registered	154	No informacion registered	No informacion registered	No informacion registered

Source: Authors' review of statistics from the registry or information offices of the UCR, TEC and UNA and personal communication with a UTN official
[a]According to a university official, this information corresponds only to the year 2015–2016. No information was available for other years

These findings are alarming because they clearly demonstrate a systemic pattern of invisibility across public universities that contradict well-intended national policies of inclusion.

In Latin America, just like in the US, there is a strong correlation between ethnic groups' education and socioeconomic status (NRC, 2012; Senior Angulo, 2007). In this sense, educational exclusion has a severe impact on people's quality of life, as it is one of the main mechanisms of social mobility. In addition to invisibility, the data shown in Table 7.3 also exposes the gross underrepresentation of marginalized groups in institutions of higher education. According to the last national census, the percentage of Indigenous Peoples is 2.47% (the total population of the country is 4.3 million, INEC, 2013). Even though this percentage may appear small, it includes eight different indigenous groups with distinct languages, cultures and territories who enrich the unique cultural diversity of the country (and of the planet). Although important efforts have been made in Costa Rica to achieve basic literacy, the latest data indicate that 20.20% of the population has no education or has not completed primary school. The latest national census also indicates that 10.4% of the Indigenous population cannot read or write in Spanish, and this ethnic group's average formal schooling is around 5.7 years, which corresponds to incomplete primary school. Given that there is a correlation between schooling and employment, in the Indigenous population the unemployment rate is around 59.3%, and the 40.7% who have formal employment work mainly in agriculture (i.e., autonomous crops and husbandry) (INEC, 2011).

In the case of Afro-descendants, they represent 7.8% of the total CR population according to the national census (INEC 2013). More specifically, 6.7% of the population self-identify as Mulatto/a and 1.1% identify as Black. In terms of education, 13.8% of the Black population and 20.8% of the mulattos/as have no education or completed primary school. This percentage increases to 38% in rural areas for both cases. Regarding school dropout, 68% of Afro-descendants between the ages of 6 and 24 are enrolled in an educational institution, with the attendance and resilience of women being greater. A revealing fact is that only 56.7% of Black men between the ages of 6 and 24 are enrolled in the formal education system, the lowest percentage recorded among all population groups. Regarding higher education, only 9.3% of the 25-year-old Afro-descendants have completed their studies, compared to 16% of the White or Mestizo/a population of this same age group (United Nations, 2013).

Returning to the construct of teacher ethnic/cultural identity, why is any of this information relevant to the aims of this chapter, as well as to the aims of our research project with secondary science pre-service teachers? We argued that *all* of it is absolutely relevant. First of all, since this project is guided by sTc, one of our main goals is to help pre-service science teachers become effective cross-cultural responsive and inclusive teachers. This cannot be achieved without fully understanding the institutional and cultural context in which we are currently working as teacher educators, and without fully understanding the cultural school contexts in which the pre-service teachers will likely find employment. Second, in order to promote critical cross-cultural awareness, everyone (instructors and students) must engage in an examination (reflexivity) of how our multiple positionalities might facilitate and/or impede our work as equity-driven instructors. Through the dialogic conversation and reflexivity, we propose that these kinds of critical discussions can be promoted openly in order to help pre-service consistently make important connections among curriculum, pedagogy, equity, diversity and social justice issues, as well as with their students' culture and experiences.

Another important aspect promoted by sTc is critical positional praxis or transformative action. This action can occur at the individual and/or community level in and out the classroom. The main goal being not to just to be a passive observant in one's own or other people's lives (either as a researcher, instructor or student). Instead, the goal is to actively apply new knowledge and insights to effect transformative change (agency). Therefore, as faculty members, we wanted to model how to promote long-lasting change and student advocacy to the participating pre-service teachers by using the new insights gathered regarding the contradiction between the university inclusive policies and the invisibilization of marginalized groups. We share these efforts next.

7.5.3 Transformative Action: Seeking Policy Changes and Raising Cultural Awareness

Our findings regarding the invisibility of marginalized ethnic groups gathered a lot of interest from various sectors of UCR. We met with a representative member of the Consejo Universitario (CU, University Council). The CU serves a similar function as a university senate does in the US, but with much power. That is, based on Rodriguez's personal experience as a former university senator at various universities in the US, and as the former Chair of the University Senate at Purdue University, University senates in the US tend to have very little power to influence major university policy changes.

During our meeting, the CU Member offered to write a resolution based on the data we shared on the invisibility of marginalized groups by UCR and other universities. He was confident that his resolution would receive strong support and that it should prompt the university administration to take action. The eight-page resolution argues in detail the need to make significant changes using already established inclusive university policies. In addition, the resolution draws attention to significant Latin American and United Nations' human rights policy documents.

In short, the resolution calls upon the UCR Administration to:

1. Recognize that the Costa Rican population is multiethnic and multicultural and to identify these groups.
2. Acknowledged that in the national territory and within the university community there are groups of vulnerable people who are not currently being recognized.
3. Implement a fixed mechanism throughout the school year that allows continuous monitoring of these ethnic populations within the university, so that eventually different indicators can be developed and affirmative action taken in favor of them (draft resolution, CU x-2021, p. 7).

During the time of writing this chapter, the resolution was being submitted for consideration. In any case, we were pleased that through CPP, we went beyond raising cultural awareness and reflection among the project's participants and university officials, we instigated transformative action that could lead to significant and long-lasting policy changes and practices.

7.6 Conclusion

We have shared findings from an on-going research project with secondary science pre-service teachers (PSTs) at the University of Costa Rica. While the focus of this study was to enhance PSTs' understanding of how to integrate critical cross-cultural pedagogy and curriculum with STEAM (science, technology, engineering practices, arts and mathematics) education, the emphasis of this chapter is on the importance of teacher ethnic/cultural identity development. Because our project is guided by sociotransformative constructivism (sTc), this framework enabled us to zoom in on teacher ethnic identity as this construct unexpectedly became a significant and puzzling point of dissonance among the research team and participants. Guided by sTc's dialogic conversation and reflexivity, the research team took steps to investigate and deconstruct taken-for-granted understandings of what we meant by ethnic/cultural identity from both the US and CR's perspectives. We also explored the role teacher identity development can play in becoming an effective culturally responsive and inclusive science teacher dedicated to advancing social justice issues. The insights gathered from our analysis strengthened the direction of our project and our ability to better assist PSTs explore their own ethnic/cultural identity (or multiple positionalities).

Our findings also show that these efforts helped PSTs build better conceptual, pedagogical and practical connections as they were being exposed to integrated cross-cultural education with STEAM science activities. This transformative aspect, or critical positional praxis, was evident in the PSTs efforts to purposely integrate in their lesson plans and practice teaching: gender issues (e.g., guiding discussions with their students about the low participation of women in STEAM); the contributions of Indigenous and Afro-descendant peoples to science/STEAM; how socio-economic status affect access to science education, health, and other resources (e.g., clean water); the relationship between environmental and social class issues, and many other aspects. We are currently analysing this component of the larger study, but it is consistently clear that the PSTs moved from seeing science as a canonical and decontextualized content knowledge to seeing science as a culturally and socially relevant subject that can (and should) be connected to students' everyday lives. This perspective then requires a better understanding of students' and one's own ethnic/cultural identity (or multiple positionalities). Becoming critically aware of how one's own ethnic/cultural identity influences interactions with others can facilitate learning for understanding and transformative change.

Congruent with the notion of critical positional praxis (CPP), or the space where we choose to turn new insights gathered from reflexivity and dialogic conversations into transformative action, we also sought to impact a taken for granted policy regarding the invisibility of marginalized groups at the UCR. In fact, this policy (which seems to stretch across other universities in CR) contradicted the country's new education reform efforts and the UCR's own policies for increasing the participation of traditionally marginalized groups in STEM-related fields (and higher education in general). By *not* monitoring the number of Afro-descendants/Black and Indigenous Peoples enrolling at the university, the UCR was de-facto invisibilizing these ethnic groups and making it impossible to provide any services and support to increase recruitment, retention and success.

Our CPP efforts resulted in the submission of a resolution to the University Council (a faculty-led representative body) by a representative member who took interest in this issue. The resolution was written in hope to change the invisibility university policy and institute significant monitoring and support mechanisms for marginalized student populations instead. We also hoped that these efforts served to illustrate to the participating PSTs how CPP can lead to significant and long-lasting change if we choose to act on insights gathered through reflexivity and dialogic conversations.

We wish to also stress and revisit the challenges we first encountered when seeking to secure support for this project. Funding agencies and universities should provide more opportunities for funding these types of international collaborations. The multiple points of inflection that international collaborations could generate to advance science/STEAM teaching and learning should not be taken for granted. For instance, the analysis shared in this chapter was triggered by a single and common US-centric expectation: to ask participants to share their ethnic/cultural identity.

This "simple" question turned out to be much more complex, interesting and impactful than we ever expected in this CR context. Similarly, these findings speak to the importance of improving recruitment and retention efforts of traditionally marginalized groups in science education (and teacher education in general in both countries). One cannot help wonder how much richer and complex our dialogic conversations with one another and the PSTs about ethnic identity would had been if we have had pre-service teachers who identified as Black, Afro-descendants, Afro-Latina/o or Indigeneous in our classes. This is an issue that the first author continuouly raised at his former home institution for 9 years where the elementary pre-service teacher population consistently is about 98% middle-class, monolingual, female, and of Anglo-European descent (or White as most of them self-identify). Having cultural diversity in the classroom (at any level) that mirrors that of the country can facilitate multiple entry points for dialogic conversations and for personal and professional growth.

In sum, our findings reinforce multiple calls for teacher education programs to improve their recruitment and retention efforts of culturally underrepresented students, as well as to make identity development a significant component of their commitment to the professional preparation of teachers as responsive and culturally competent professionals.

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Chapter 8
The Journey of Decolonization as a Scientist and Science Education Researcher

Rasheda Likely and Christopher Wright

> Decolonization is an emotional process; not in the simplistic way ascribed to non-white peoples by white supremacy, but in a way that goes beyond, goes deeper, goes further than reason can reach (Sium et al., 2012, V).

As I reflected on my trajectory in becoming a biologist, I came to understand the processes and experiences that informed how I defined and conceptualized what it meant to engage in scientific practices and become an authentic member of the science community. Since elementary school, science has always been one of my favorite subjects. I was fascinated with the systems, structures, patterns, and cycles found in science content. My attempts to learn big words, ideas, concepts and follow detailed processes continued through high school and undergrad. Participating in lab activities accounted for some of my most memorable and enjoyable experiences during high school and college. I fondly remember the opportunities to wear safety goggles and white lab coats, to carefully mix chemicals, to meticulously work on lab benches and analyzing science conference posters that were on the walls and hallways throughout the lab. All these elements were instrumental in my learning and development of a strong science identity. Despite my unwavering love for science and desire to become a scientist, it became evident that the practice of memorizing vocabulary words emerged as an essential skill for achieving academic success in these contexts. Even during my experiences of pursuing a Masters of Science in Biology, memorizing and reproducing the content for the test was the most efficient way of being successful. Additionally, my undergraduate and

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graduate courses, labs thesis advisor, graduate program supervisor were mostly led by white male professors which stood out to me as a Black female student. I took note that in higher education spaces, I had four female science professors, and only one was a woman of color. I spent more than 5 years in undergraduate and graduate science spaces learning content, practices, ways of thinking, evaluation, and skills from a majority of white men. These were the people evaluating my understanding of science concepts through tests and quizzes. They expressed their understanding of who a scientist is and what a scientist does through the way they ran their labs and over time, that way was what I also emulated. I earned a job after college as a medical testing scientist during the height of the Zika and Ebola virus outbreaks. The difference between that lab and my educational experiences was that instead of the team being predominantly white and male, there were four white female scientists. Although new protocols and procedures were unfolding, we mainly worked individually and siloed without socializing beyond birthday celebrations in the kitchen area. However, after experiencing science learning and skills up to that point, I had learned to do my best to fit in. Often being the only Black person in a lab, I knew how to assimilate into the science spaces. Some assimilative practices and performances in this context ranged from feeling the pressure to always be fluent in science vocabulary, not asking questions too often in order to seem full of information, consciously representing Black people since I was the only Black person in the lab, and paying close attention my physical appearances, especially that of my hair. I often changed the style of my natural hair which historically for Black women has been associated with gender, class, and beauty. In the testing lab, wearing my hair straight or in a braided style was the talk of the lab for days which one time included the comment "I like your hair straight. Seems more professional." How were my curls less professional? Why would my hair be of concern when I do not use hair in my work? Yet, my co-workers made audible comments to me and each other about my hair. To avoid being the focus of group conversation, I refrained from certain hair styles which included continuing to straighten my hair. Eventually, I came to understand science and self-expression in science spaces was something afforded to white people, especially white men. Lab spaces were only for calculated discovery. The physical materials such as glassware, chemical ingredients, goggles, and white coats were used in science labs and only by scientists. Science was serious work exclusive to a certain group of people that had earned their place in the space. From these years of training, I understood that becoming a practicing scientist meant that I did not always use the words and phrasing I did with my friends and family. I also learned that academic assessments were the main evaluation method of knowledge and understanding. Memorization skills, in particular, ensured me a high score on standardized assessments. Other forms of assessment such as projects beyond a lab notebook, storytelling, or a narrative format were not used in science spaces. I also learned that in the lab setting, expressing myself through my hairstyles was also out of the question or else I became the focus of the few lab conversations that included my hair's level of professionalism. I learned how to maneuver these science spaces by talking differently, using certain words, memorizing content, and lowering my self-expression to stay in the spaces with the least friction. Assimilating into the existing cultures was the way I survived in the lab space. I slowly yielded to the pressures that existed for me there. My experiences with science were colonized to the point I no longer was able to separate myself from the limiting and restricting ways of learning and being that mostly benefited white men. When approaching my dissertation study and considering the design of science curriculum to be taught to secondary level students, I wanted one that could be more applicable to daily scenarios and reflective of cultural practices. But how was I to do that when I had not experienced it? Centering a science curriculum around Black hair care required a decolonizing of my own understanding and practices of science. That process was not easy.

8.1 Decolonization as a Theory

Radical processes for liberation through decolonized curriculum and assessment strategies are supportive for those experiencing oppression due to colonization and racism. New "tools" for decolonization within science education are required "for the master's tools will never dismantle the master's house" (Lorde, 1997, p. 5). Sium et al. (2012) posit decolonization as a "rearticulation" of power by not recreating a similar system with the stratification of marginalized or oppressed groups (p. III). Decolonization is a theory and dynamic process that focuses on expansion by including and integrating more values than the dominant one (Tavernaro-Haidarian, 2019); thus, requiring it to be intentional as much as it is critical and anti-racist in theory (Tuck & Yang, 2012). Battiste (2014) and Higgins (2016) argue for a two-step process of decolonization: (1) deconstructing structures that are oppressive to minoritized groups and (2) restructuring of experiences through centering culturally sensitive ways-of-knowing (see Fig. 8.1). As such, we are following Crenshaw (1991) and will be capitalizing *Black* as a proper noun referring to a specific cultural group and not *white* since it does not reference a specific cultural group throughout this chapter.

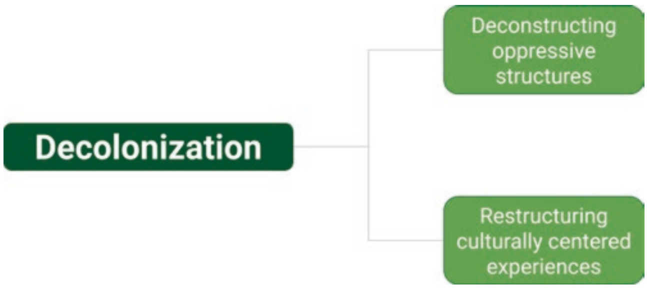

Fig. 8.1 Decolonization as a two-step process of deconstructing oppressive structures and restructuring culturally-centered experiences. (Battiste, 2014; Higgins, 2016)

8.1.1 Decolonization as Praxis

In order to bring to fruition a science experience for Black girls that was asset-based and incorporated knowledge and cultural expertise through the engagement in science practices, the first author with the guidance of the second author developed a curriculum with assessments that were culturally derived and centered. A primary goal of the curriculum was to push against the normalization of Whiteness in science education by centering on Black hair and hair care product making. Ashley and Brown (2015) suggest that for Black women and girls "hair care can provide a context and vehicle for attachment, nurturing, and positive self-worth" (p. 1). Overtime for Black women, a '[Hair] style could lead to acceptance or rejection from certain groups and social classes, and its styling could provide the possibility of a career" (Rooks, 1996, p. 5–6).

For many, natural hair was considered a problem to be fixed by straightening, since straightened or relaxed hair allowed a Black woman to seemingly appear more professional, attractive, and ultimately closer to Whiteness (Mercer, 2005; Okazawa-Rey et al., 1987; Thompson, 2008). "Hair acts as a figurative and corporeal stage for analyzing how Blackness, gender, class, and beauty are performed, in essence, 'done'" (Jacobs-Huey, 2006, p. 87). By removing natural curls, coils, and kinks, Black women were able to remove culturally identifying markers to gain access to employment, decrease discrimination in social settings, define the beauty standard through modeling, and gain acceptance into predominantly White spaces (Ford, 2015; Mbilishaka, 2018; Rooks, 1996; Thompson, 2008). This phenomenon explains the attachment and nurturing many Black women and girls experience with their hair care practices. However, the way culture and activity systems impact learning have not been sufficiently studied or researched (Bang, 2015).

In this chapter, we present the process the first author took to explore and understand what it meant for a self-identified Black woman scientist to design and implement a science curriculum and inquiries that highlighted Black hair and skin care. Using a critical autoethnography methodology, this research investigates the question: *what is the process a self-identified Black woman scientist took in order to design and implement a science curriculum that highlighted Black hair and skin care*? The inclusion and representation of Black girls within science curriculum challenges settled hierarchies, irrelevance, and disinterest within STEM experiences. However, through the application of decolonization beyond a theory required more than the two-step process of identifying and restructuring. The explicit and intentional disruption to settled hierarchies within science education through decolonization has led to this project not being readily published as of yet. It is our hope that sharing the intimate experience decolonizing one's own practice will support researchers, curriculum developers, editors and other publishers to be introspective if they apply such critical frameworks.

8.2 Theoretical Framework

Hierarchies within science education are a result of the influence of Whiteness through colonization and the concretizing of Whiteness as a "culture of power" (Aschbacher et al., 2010, p. 564) through curriculum, instruction, and assessment. Here, Whiteness is defined as "the production and reproduction of dominance rather than subordination, normativity rather than marginality, and privilege rather than disadvantage" (Frankenberg, 1993, p. 236). Overall, Whiteness is more than how people see themselves; rather, Whiteness is a product of dominance, subordination, and privilege. The identification and naming of colonized, settled, and oppressive norms and practices within education have been presented through various works. For example, there has been much critique of the use of data that problematizes the achievement gap (Gutiérrez, 2008) between Black and white students without considering the racial biases that exist within assessment instruments. Another example is the assimilation and lack of cultural diversity necessary to be recognized as thinking or behaving like a scientist (Aikenhead & Elliott, 2010). The presumption that there is a very narrow expression of science thinking and doing is a result of Whiteness being atomized in the structure of science as a discipline (Mensah & Jackson, 2018). These "traditional" ways are examples of how science experiences have othered and marginalized the intersectional experiences of Black girls. The first author was not exempt from internalizing and acting on these science traditions that were altogether harmful and restricting during her journey as a scientist. Yet, separating herself from these ideals led to deep grief due to the loss of attachment to colonizing science. In the next sections, we define a science attachment then expand on attachment theory and loss as the theoretical framework.

8.2.1 Attachment Theory and Loss

Psychologist J. Bowlby details attachment theories and loss of attachment through analyzing systems of behavior. Bowlby (1980) suggests that "feedback, continuous account is taken of any discrepancies there may be between initial instruction and current performance so that behavior becomes modified accordingly. Attachment behavior has become a characteristic...because it contributes to the individual's survival..." (p. 39–40). Black girls in STEM at times experience othering and separation (Keller, 1985), erasure (Tobin et al., 1999), disinterest (Roth & Lee, 2004), isolation (Rosa & Mensah, 2016), and irrelevance (Herzig, 2010; Ireland et al., 2018). In the introductory vignette, the first author recalled instances where assimilation to the white male-led science spaces experienced through usage of scientific vocabulary and acutely being aware of hairstyles was for her overall benefit in science spaces to combat othering, isolation, and irrelevance. In agreement with, it is these settled hierarchies that "can profoundly shape who and what is seen and heard as scientifically meaningful" (Rosebery et al., 2016, p. 1573).

Over time, behaviors such as, promoted individuality, vocabulary recall, usage of science terminology, and lack of self-expression were no longer choices for participation but based on feedback necessary for survival in said science spaces and to be recognized as thinking or behaving like a scientist (Aikenhead & Elliott, 2010). These actions were part of the first author's success in science spaces through research labs, testing labs, and college science labs although none of the science experiences were reflective or inclusive of Black and/or female scientists. These norms were internalized leading to the specific attachment to colonized science; therefore, making the process of developing and implementing a decolonized science curriculum extremely difficult. She found herself dealing with the loss of familiar, colonized ways of understanding in order to develop and implement decolonized science activities and expanded assessment modalities.

In order to create such a curriculum, the first author had to participate in a deep, personal process of unlearning and detaching from 10 years of traditional training, teaching, and research as a biological scientist. Designing and implementing an asset-focused, culturally-based decolonized curriculum without a template or precedent, required intentional design for disruption of settled hierarchies within science education. Further exploring the oppressive powers of race, gender, and class on the Black women "shed new light on how domination is organized (Collins, 2000, p. 227), including science education.

Preparing to develop a decolonized science curriculum and assessment meant to apply the two-step process (1) deconstructing structures of oppression and (2) restructuring experiences through centering culture. However, what was discovered through the process of decolonization was a third step of grief due to the separation from the attachment of colonized science. Bowlby et al. (1989) highlight four stages of grief associated with the loss of attachment: (1) numbness, (2) yearning and searching, (3) disorganisation and despair, and (4) reorganisation (see Fig. 8.2). Decolonization required separating the attachment to the traditional training in

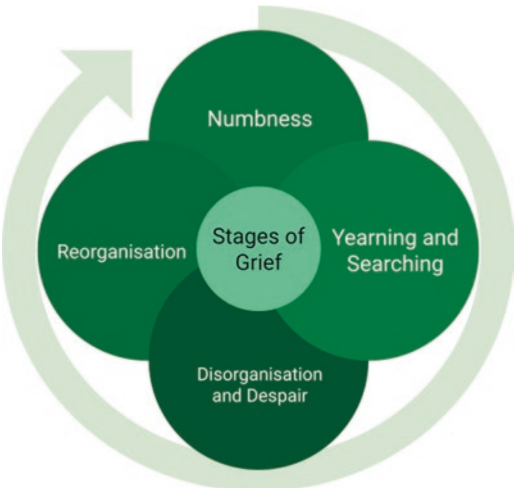

Fig. 8.2 The four stages of grief associated with the loss of attachment as a cycle of numbness, yearning and searching, disorganisation and despair, reorganisation. (Bowlby et al., 1989)

order to fully deconstruct and identify structures of oppression within science and center culture through science curriculum. In the next section, we present the methodology used to investigate this journey of decolonization for a Black female scientist experienced.

8.3 Methods

In this section, we outline critical ethnography as the methodology for investigating the ways a Black female scientist approached developing and implementing a decolonized science curriculum. Using this methodology, we answered the question "*what is the process a self-identified Black woman scientist took in order to design and implement a science curriculum that highlighted Black hair and skin care*?' This section concludes with the curriculum that was developed and how it was implemented.

8.3.1 Critical Autoethnography Methodology

To present this complex journey, we use critical autoethnography methodology that combines ethnography, autobiography, and critical pedagogy. We chose this qualitative method to allow for the examination of self, systematically and transparently, while considering and challenging dominant social realities (Boylorn & Orbe, 2014; Ellis & Bochner, 2003; Hughes & Willink, 2015). The first author identifies as a Black woman who is part of a marginalized and minoritized population within science, technology, engineering, and mathematics (STEM) (Tan et al., 2013). In particular to STEM, these matrices have been conceptualized as the double-bind (Ong et al., 2011), where women of color experience matrices of domination within STEM workplaces and educational settings because of perpetuated Whiteness (Morton & Parsons, 2018).

Moreover, we chose to implement a methodology that considers the impacts of historically and perpetuated norms with intersectional identities like a Black woman within the field. "The intersection of racism and sexism factors into Black women's lives in ways that cannot be captured wholly by looking at the race or gender dimensions of those experiences separately" (Crenshaw, 1991, p. 1244). Black girls have experiences at distinct intersections that have impacted their interest and persistence in these STEM disciplines (Johnson et al., 2011; Ong et al., 2011). Through a critical autoethnography, we highlighted "the world of educational research in ways that go unnoticed" (Marshall & Barritt, 1990, p. 594) such as the racial and gendered experiences of the first author, a Black female scientist and science educator. Since colonization results in the dehumanizing and erasing cultural norms and identifying characteristics, decolonization requires the centralizing and celebration of culture.

8.3.2 The Design of the Lotions and Potions Curriculum

Lotions and Potions: Science through Hair Care is a culturally sustaining science curriculum that foregrounded cultural elements of Black hair care product making as the object of scientific inquiry and exploration using the foundational framework of decolonization. The focused interaction of this curriculum was for students to investigate skin and Black hair as science content and use the making hair care products to participate in science and engineering practices (NGSS Lead States, 2013). Each lesson had a packet with science content explanations, materials lists, instructions to make a product, journaling section, and activity pages for a total of 67 pages (see Fig. 8.3). The content, figures, and models for the curriculum were referenced from *The Science of Black Hair* by Audrey Davis-Sivasothy (2011). The hands-on activities and Do-It-Yourself (DIY) products were designed to have the students directly engage with the making process and participate in science and engineering practices. The lessons in the "Lotions and Potions: Science through Hair Care" curriculum followed a framework of disciplinary core idea, hands-on activity, and assessment of science and engineering practices (see Table 8.1). The formative assessment in Lesson 1 were the observations the students took of the learning lab. Lesson 2 was focused on the layers of skin, organs in the skin, and hair as a human product. The materials and instructions provided in Lesson 2 for the hands-on activity were to familiarize students with the template of making activities and the presentation of materials and steps. Additionally, this lesson also introduced the concept of hair patterns and how to identify various types of hair patterns to highlight the science and engineering practice of developing and using a model. The formative assessment in this lesson afforded students to make observations about hair patterns and the

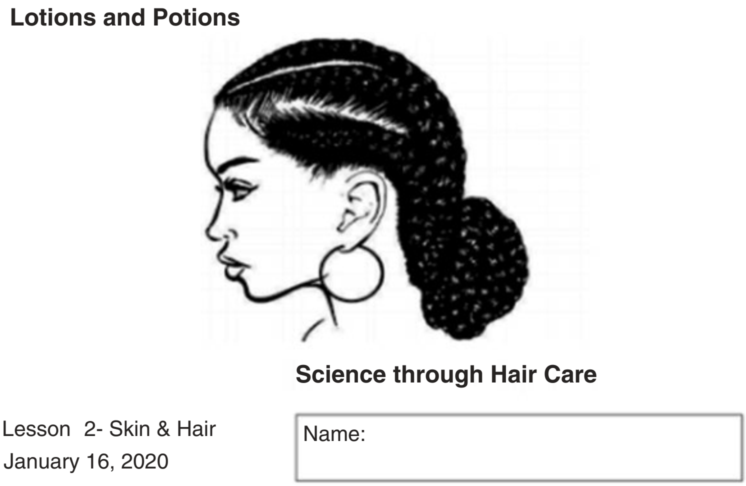

Fig. 8.3 Image from the front of the packets that students received each lesson with "Lotions and Potions"

Table 8.1 Outline of the "Lotions and Potions: Science through Hair Care" curriculum

Lesson	Hands-on activity/DIY product	Science and engineering practice	Formative assessment
Lesson 1: Introduction	"Around the room observations"	Obtaining, evaluating, communicating information	Observation statements
Lesson 2: Skin and hair	"Skin elasticity"	Obtaining, evaluating, communicating information	Observation statements
		Developing and using a model	Hair pattern modeling
Lesson 3: Soap	"How soap works"	Using a model	Fill-in the blank
		Using a model	Label the diagram
		Using a model	Label the hair pattern
Lesson 4: Lotion	Hair lotion	Constructing explanations	Matching
Lesson 5: Hair oil	Hair oil	Engaging in argument from evidence	Pair-share activity
Lesson 6: DIY video	DIY video	Engaging in argument from evidence	DIY video

opportunity to develop models of their hair pattern. The formative assessments in Lesson 3 were fill-in-the blank, label the diagram, and label the hair pattern which required the students to participate in using hair and skin models available in the room. Lesson 4's formative assessment was a matching activity to scaffold scientific argumentation before the students made their second DIY product, lotion. Scientific argumentation was one of the science practices that was highlighted as a trajectory guided by the curriculum and explored further in a later chapter. The content area for Lesson 5 was moisture for the hair strand using hair oil. The students began the class with a pair-share activity as a formative assessment. The students had completed two of the three product making classes and three out of four classes with new content. Rather than situate the "think" alone then pair into groups, students worked together to address one of three prompts then share with the class. Lastly, Lesson 6 was focused on producing the DIY video as the formative assessment. The students were given the option to choose from a list of topics and products to present in their DIY video. The DIY video served in the curriculum for the trajectory of scientific argumentation which is analyzed in a later chapter.

Although the results of this intervention provided insight into the ways middle school Black girls engaged in science and engineering practices through a hair care curriculum, the development of the curriculum brought a large shift in thinking about curriculum for the first author. In an effort to decolonize science experiences, the packets featured coloring pages of Black girls served as a mirror of representation (Bishop, 2012) and relevance within curriculum (Banks & Banks, 2004; Quiroz, 2001). Additionally, addressing individualism through collaborative efforts among STEM spaces would directly address the isolation that affects perseverance of Black girls and women in STEM (Ireland et al., 2018; Rosa & Mensah, 2016). Additionally, these images were to directly combat Eurocentrism that is reproduced in science materials and resources (Higgins, 2016). To decolonize science experiences around isolation, students worked in groups of two throughout the lessons. Lastly, the first author focused on students seeing one another as sources of knowledge rather than just the worksheets or the teacher. Following Engle and Conant (2002), students engaged in sense-making through (a) identifying a question or problem (b) taking authority in approaching the problem, (c) approaching a solution and reason collaboratively, and (d) were supported in resources like the teacher, worksheets, and internet access.

8.3.3 Participants and Context

The implementation of the curriculum, "Lotions and Potions: Science through Hair Care" after-school class, ran for six classes, twice a week for 90 minutes each class, totaling 17 plus hours of contact time in January 2020. The site of this research took place in an interdisciplinary lab at a private university in Philadelphia's (PA) urban center. Ten, Black middle school girls in grades five through seven, ages 10–13, were recruited through a flyer distributed to several local after-school programs. The inclusion criteria for this project were enrollment in middle school and to self-identify as a Black girl.

8.3.4 Reflexivity

Following King and Pringle (2019), the first author positioned herself through this work as a researcher, curriculum developer, and class facilitator. Through intentional reflexivity throughout the development, implementation, and analysis of the *Lotions and Potions: Science through Hair Care* dissertation study, we understand the research presented in this chapter as part of a larger movement inclusive of experiences and societal issues of Black girls within STEM spaces (Butler, 2018). Probst and Berenson (2014) explain reflexivity as an "awareness of the influence the researcher has on what is being studied and, simultaneously, of how the researcher process affects the researcher. It is both a set of mind and a set of actions" (p. 814). That reflexivity as a set of mind and actions is the focus of this chapter. In the next sections, the type of data collected and analysis plan are outlined.

8.3.5 Data Collection

Inclusive of dramatic recall and retelling as the data (Richardson, 2000), data for this critical autoethnography were collected while the first author was in a four-year doctoral student being supervised by the second author in the second, third, and fourth years of the doctoral program. The first author kept a research journal during the entire doctoral program. The first and second author met weekly to discuss in-process research projects, dissertation research planning, and other administrative details. As a part of the doctoral program, the first author organized a committee of five faculty members who were responsible for reviewing the dissertation proposal and final dissertation document.

The data for this study included journal reflections in the second, third, and fourth years of a four-year doctoral program, weekly advisor/advisee meeting notes, second, third, and fourth years, reflections collected after each dissertation class, and dissertation committee feedback in year three. The authors engaged in two cycles of coding, beginning with an open coding approach for identifying initial categories or themes (Creswell, 1998; Miles et al., 2014; Patton, 2002) then a second round of axial coding provide the opportunity to organize the initial codes into larger and related themes as aligned with four stages of grief.

8.4 Findings

In the next section, we outline how the loss of the attachment to Science expressed through the development and implementation of the culturally sustaining curriculum *Lotions and Potions: Science through Hair Care* led to grief. Throughout the remainder of the findings section, the first author, a Black female scientist and science educator, assumes the pronouns *I/me*. Although it is understood that the stages of grief are not linear, the transition through each stage is chronological from the development of the curriculum through the implementation of the curriculum.

8.4.1 Numbness

After experiencing winter in Philadelphia during the first year of the doctoral program, I started making my own hair and body lotions out of the need for more moisture in the drier, colder North East climate as compared to Florida where I was from. I enjoyed making products since it required the same skills and practices of science lab research and testing such as planning, measuring, mixing, and analyzing results. I also was very focused on figuring out a research path during the second year of the doctorate program. There was little to no connection from my personal life and my learning. Science had taught me to separate personal interests and ideas from scholarly research. By the start of my second year in the doctorate program, I was in the process of shifting supervising professors. Up until that point, the main topics I was exploring were underrepresented minorities in STEM, student perseverance in STEM, and teacher training. Particularly, I was interested in "features in the curricula that make it useful for teachers… What resources support teachers with the Next Generation Science Standards 3D frameworks" (journal notes January, second year) and “Anything with gender, race, and Biology...like why do women choose Biology or other subjects in STEM?” (meeting notes). I had few ideas about research topics, but none of them deeply personal, but all relevant.

At the annual national educational conference in April of my second year was the first time I was attending the events with my advisor, the second author. In a few conversations, I had mentioned to him how making hair products should be in science labs, but it was just something fun to do at home in the kitchen. While at the conference, he introduced me to several science education professors and researchers. He asked that I share my research interests with them. I recall sharing my thoughts about teacher resource materials and professional development opportunities. After I had finished that sentence, he said “No, tell them about the hair care.” This was the first time verbalizing that hair product making was science and connected to science practices. In my notes from that day, I wrote “I had NOT practiced that speech before. Can hair care even be a science practice? I don’t know. I don’t think so. I did not like being put on the spot… when did I ever do hair care in a science lab? I would rather never talk about that again. I need a project that is solid. Not one that I am making up. Absolutely not. How embarrassing! A second year student {that is} not even sure of their research ideas!” (journal notes April 15).

The idea of introducing something as personal as the hair products I made in my kitchen into my science education research plans felt wrong, impossible, and “not science-y enough”. It was easier to ignore the pain that was felt when I was asked to connect science in a different way. I had not seen things like that done before. I was not sure it could be done. I did not want to “betray” Science. The thought alone was overwhelming, shocking, and ultimately resulted in numbness. After that interaction at the conference, I did not revisit the hair care curriculum except for a brief mention of “chemistry- hair products, lotion...co-constructing something” (meeting notes).

8.4.2 *Yearning and Searching*

During the next few months, I was preparing for the dissertation proposal which has to be completed by the end of the third year in the doctorate program. It was during these moments that I was beginning to see that I could no longer hold fast to the structure of curriculum content, design, and assessment that I was most familiar with from Science. I had been enjoying reading about the theory of decolonization. Particularly, I was learning and understanding more about the concepts and strategies that were useful to applying decolonization beyond a metaphor. However, examples of decolonization in science education were limited. The searching for examples and precedents left me wanting to see how decolonization was used as a theoretical framework especially. “Find methodologies for how to frame this work. What will be the design of the curriculum?” (from advisor meeting).

During these moments, my yearning for a template or example of the application of decolonization was very clear. My large questions were at this time “What are the measuring pieces? How can we see what students are learning? ASSESSMENTS! What impact would my study have?" (from advisor meeting). I was searching for examples of the application of decolonization in formal and informal science K-12 educational spaces.

This time of dissertation planning was most difficult because my searching around decolonization led me to sociology research, dissertations using music and dance, and numerous theoretical and conceptual applications of decolonization. I was able to loosely connect some physics and chemistry research to hair care and hair follicle structure, but those works were not supportive of the framework of decolonization. The months of grief where I was dedicated to yearning and searching for a way to fill the void of Science curriculum and assessment development as I knew it ended with "I want Black girls to see themselves as scientists" (Journal notes from January 25). I still had outstanding questions like how will the students see themselves in the curriculum and who has done similar work before? But I was clear that I desired to develop a learning experience where Black girls were able to see themselves as scientists. I knew that meant unraveling what I knew Science to be. The journey of grief so far had led me through the numbness first experienced with letting go of science curriculum and assessment as I had experienced and taught with it. I knew that I could not replicate the science experiences that needed to be decolonized, but I was yearning and searching for a new way forward.

8.4.3 Disorganisation and Despair

It was during this time after yearning and searching for something to replace structures that were familiar that I presented my first iteration of how a decolonized middle school science curriculum about hair care could look. I defended my Dissertation Proposal in June of my third year to a committee of five faculty members. I had chosen four faculty members in addition to my Black male advisor to serve on my dissertation committee, two Black women and two Black men. The initial purpose was to identify faculty members that did not expect or require assimilation to a culture of power that was normal for science education and would make space for a dissertation project that could celebrate, encourage, or affirm ways of talking, seeing, and being in the world (Bang et al., 2012; Brown, 2004) that was not often seen in science education. These faculty members had deep expertise in areas of curriculum and instruction, identity development, and STEM education. I was certain that they were the best people to offer feedback on my evolving thoughts around a hair care science curriculum and appropriate assessment development.

Based on their feedback, I had not applied decolonization as my foundational framework. At that time, the proposal was supported by three research questions: (1) How is student learning of the macromolecules impacted by participation in a culturally sustaining science curriculum? (2) In what ways do students participate in scientific argumentation while engaging with a hair-care curriculum?, and (3) How are students perceiving scientific engagement and practices while experiencing a culturally sustaining science curriculum? Each of the committee members made expressions such as “What’s more important, the curriculum or the students?” which challenged where the focus of my dissertation was placed. The one comment that was most jarring during that review process was “Either you’re going to decolonize or you aren’t” which prompted me to review my entire dissertation proposal document. A brief content analysis of the 69 page proposal revealed the word *decolonize* was used only twice throughout the entire plan for the dissertation project. What the committee expressed is what I had been struggling with up to this point mainly the question “Does making hair care products constitute as science?” The committee strongly suggested refocusing the research to highlight decolonization in curriculum and assessment, ultimately leading directly to my disorganisation and despair around finding a better way to express the connections of hair care to science.

> I didn’t know how angry I was. I didn’t know who I was angry at. I just knew I was angry. I had to re-do THIS MUCH… the regular science stuff isn’t expected of me. People aren’t asking me to do what I know. Repeat what I know to be science learning and evaluation. But they aren’t telling me what it should be! I’ll acknowledge this anger, but what’s the point? I have to use this energy some kind of way. Channel it into a better way to do science I guess. But I don’t know how to do that OBVIOUSLY. (Journal notes July 23)

As a result, the first drafting of the “Lotions and Potions” curriculum had not fully removed traditional science experiences such as classroom power dynamics, high stakes testing, and limited expression of science understanding. Additionally, although I was centering hair care, the curriculum had the potential of being additive to current curricular resources rather than transformative (Banks & Banks, 2004). Ultimately, I desired to develop a transformative science curriculum that centered and affirmed Black hair culture, yet I had not fully imagined a decolonized science experience for Black girls. I was unsure how to proceed and was upset about the need for much reorganisation of the dissertation proposal when there was no sufficient template for this decolonization work. The attachment to colonizing science was most familiar and could be replicated easily since it had been internalized; however, the dissertation projected was focused on decolonizing and disrupting these attachments that ultimately led back to Whiteness as property and power in science.

8.4.4 Reorganisation

After defending the dissertation proposal, the feelings of disorganisation and despair were still very strong, but I had committed to teaching three of the lessons of the *Lotions and Potions* curriculum in two summer programs. After engaging with the summer program students who most of which identified as Black and observing the ways they were asking questions, developing and using models, and engaging in argument from evidence, I was encouraged to reorganize the overall plan for the

Lotions and Potions curriculum in a way that was informed by decolonization regardless of my personal attachments to colonizing science.

Considering the students experiencing the curriculum were Black, and I was a Black teacher leading these science lessons, in both settings, the after school lessons occurred beyond the White gaze. Paris and Alim (2014) incorporate Toni Morrison's reflection on the White gaze and positions this gaze as part of the culture of power:

> What would our pedagogies look like if this [White] gaze weren't the dominant one? What if, indeed, the goal of teaching and learning with youth of color was not ultimately to see how closely students could perform White middle-class norms but to explore, honor, extend, and, at times, problematize their heritage and community practices? (p. 86)

Essentially, Paris and Alim (2014) are questioning and calling for a method of teaching inclusive of curricular text that explores, honors, and extends students' various cultural expressions and ways of knowing. "What would a science curriculum that did not concern itself with the white gaze really look like?" (Journal notes July 30). After leading students through the making of hair products, I revisited the committee's feedback on the dissertation proposal. I used those teaching moments to attempt to apply the feedback that led to truly decolonize science content, experiential learning activities, and formative assessments that reordered power in a science learning space, centered student choice, and made way for the opportunity for students to be experts in their own learning.

The reorganization after hearing the committee's feedback and engaging with students while making hair products led to a large reorganization of the full dissertation research by detaching from science norms. The imperative to reconcile without transformation is reflective of appeasing and satisfying the oppressor rather than truthfully acknowledging and reimagining freedom for the oppressed (Tuck & Yang, 2012). I had to decide that the *Lotions and Potions* curriculum development and implementation would seek freedom for those marginalized and oppressed by science and science education.

The fourth-year implementation of revised lessons and assessments completed the reorganisation portion of the cycle. Reflections after each class highlight participation and engagement mostly. "The coloring pages that had been added to the curriculum of girls with different hair styles and curl patterns were a hit {with the students}. They really liked that strategy and they all shared that 'we want to color some more.' The comment sections of the curriculum were also a favorite. Students tried to press the button on the page" (After-class reflection).

The interdisciplinary lab space where the class was held required me to reorganize Whiteness as property in science education. After the students left the first-class session, I was still in the interdisciplinary lab when two white men entered. The white gaze was reintroduced to the space, and I began to ask if I was taking up too much of the work room since I had not finished clearing the worktable in the space. "The area {lab space} was tense again. And I was able to remember how just moments before the space was filled with joy, excitement, surprise, curiosity, mystery, questions, laughter, safety. The space was love until it wasn't" (After-class reflection). I had to participate in reorganising who was able to do science and what science was permissible in the interdisciplinary space in a way I had not experienced in previous science spaces.

Other experiences of reorganisation while applying decolonization was a modeling activity where the instructions were for the girls to model their current hair pattern, but I did not plan for braided hairstyles and hair patterns under wet or dry conditions. "When we discussed curl patterns, I was unable to take into account the braids. A few of them asked for more pipe cleaners to model their curls. Some of them asked for more pipe cleaners for wet and dry hair. They did bring up shrinkage on their own!" (After-class reflection). To conclude, another example of the reorganisation I experienced was the way students were encouraged to work with their partners at their own pace. "They have to get used to doing things for themselves. Being competent. They can do it. I know they can. They have to want to and try. 'At school, we can't move on our own." is what they have shared. How different is this curriculum from school? Not having the autonomy to move on to the next step" (After-class reflection).

Early renderings of the *Lotions and Potions* curriculum relied on knowledge and experiences of a "traditionally trained scientist" where limited expression of science understanding (Rosebery et al., 2016) through memorization and standardized assessment instruments led to positive outcomes in the class including high scores. However, the attachment to science through assimilating in science spaces due to practices such as memorization, lack of socializing, and muted cultural expression prevented the first author from embracing decolonization in praxis. The grief associated with losing the attachment to colonizing science was an integral part of the conceptualization and implementation of the *Lotions and Potions* curriculum. Only after reorganizing most of the curricular activities and formative assessment strategies was the curriculum able to be implemented in a way that rearticulated science learning and activities by providing a different content area, Black hair and product making.

8.5 Discussion

The *Lotions and Potions: Science through Hair Care* is a culturally sustaining science curriculum that was developed and implemented in a dissertation research study. To present a transformative (Banks & Banks, 2004) curriculum, Black hair care was centered as a science topic, and hair care practices such as Do it Yourself (DIY) product-making were used as assessment instruments. The findings presented in this chapter answer the question: *what is the process a self-identified Black woman scientist took in order to design and implement a science curriculum that highlighted Black hair and skin care*? The purpose of sharing the process of the development and implementation of the curriculum through critical autoethnography is to open conversations (Ellis, 2004) around the application of decolonization and reframe ideas around the application of decolonization. Along those lines, the first author had not been the subject of research for this dissertation project;

however, this chapter centers on the process for designing and implementing a decolonized science experience in addition to the product of a curriculum.

Attachments to science were disrupted by the development and implementation of the *Lotions and Potions* curriculum. Releasing these attachments were integral to reimagining the ways in which youth of color are provided opportunities to engage in and connect with science content (Wright, 2019). The two-step process of decolonization required the work of naming the complex, interwoven systems of oppression through extensive literature review. The work of reimagining and visioning experiences of Black women and girls in science education was preempted by deep personal work of detaching from colonized science which led to deep grief. We are expanding on our previous understanding of the application of decolonization to consider steps of grief as part of the process (see Fig. 8.4). We are supporting the process of decolonizing your own assumptions and expectations of what counts as science education research for partaking in research with girls from communities that have been historically excluded (Bang et al., 2012) from Science.

In conclusion, this study of self was important to share as concepts like *decolonization*, *transformation*, and *reimagining* are becoming more popular within science education. These theories are foundational for change and progress; moreover, these theories in praxis are also tangible and deeply emotional, unsettling, and challenging (Tuck & Yang, 2012). Scholars and communities often refer to doing "the work", and we would like to present that part of that difficult work is making space for the grief of separating from old systems and ways of thinking in order to vision

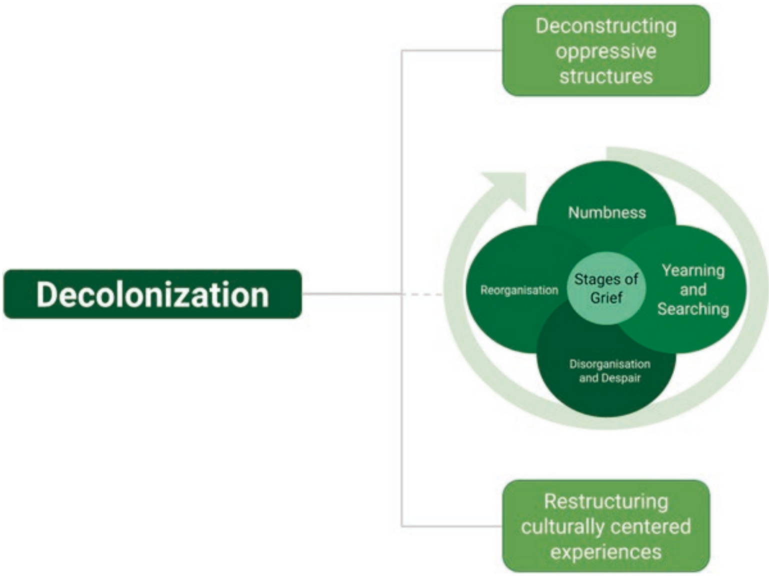

Fig. 8.4 Decolonization is a three-step process of deconstructing oppressive structures, of grief, as a cycle of numbness, yearning and searching, disorganisation and despair, reorganisation, and restructuring culturally-centered experiences. (Battiste, 2014; Higgins, 2016)

and create a freer way forward. In order to name and restructure systems without reproducing the same harms, making space for the grief associated with detaching from known and well-practiced systems should be considered. Imagining decolonization in science education means to detach from colonizing science practices. Our focus was on the grief cycle related to releasing attachments to Whiteness and participation in colonized science spaces in order to present a decolonized science experience.

Implications of the *Lotions and Potions* curriculum highlights the opportunity for curriculum developers and assessment designers to expand assessment instruments that center the active knowledge building of middle school learners through multimodal opportunities can raise sensitivity of instrument for the diversity of students. Another implication of the curriculum research is for teacher education programs to explore the ways cultural processes such as verbal expression of knowledge can be treated and acknowledged as assets (Bang & Medin, 2010) for evaluation and learning and in an effort to de-settle privileged ways of knowing within science. We are suggesting continued development and use of reflective methodologies that explore the identity development of the researchers and educators. Specifically, for "Black girls—and the researchers who work with them—are attentive to the ways race, class, gender, and additional interlocking identities… funnel into urban classrooms" (Butler, 2018, p. 29). We wanted Black girls to be able to see themselves centered in science materials and texts while considering how intersectional identities should be addressed through equitable interventions.

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Chapter 9
Striving for More: Beyond the Guise of Objectivity and Equality in Engineering Education

Randy Yerrick, Michael G. Eastman, Monica L. Miles, Ramar Henderson, and Ram Nunna

9.1 Introduction

Efforts to reform science, mathematics, and engineering education toward more equitable access have taken a variety of forms. Since the first call to equity in the form of "Science for all Americans" (Rutherford & Ahlgren, 1991) there has been continued attention and investment toward the re-examination of epistemological and cultural stances defining what it means to think, speak, and act like an expert in these three fields (Lynch, 2001; Mutegi, 2011). It was once thought that treating every student the same and offering equal and standardized measures for all students avoided bias and would rebuff any critiques who drew attention to the predominant bias of rational, positivist engineering perspective. However, a variety of scholars have recently interrogated this stance (Beddoes & Borrego, 2011; Blickenstaff, 2005; Harding, 1998, 2004; Lewis, 2003; McGee, 2016; Rice, 2016; Rodriguez, 2004, 2015). This re-examination of pedagogical, curricular, and cultural practices of the discipline translated into higher education classrooms has been informed by a variety of researchers and voices outside of science, technology,

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math, and engineering (STEM) education. Historically, there has been an enormous investment of local, state, and federal dollars towards a re-examination of under-representation in STEM. Our aim in this chapter is to provide a deeper examination of the socialization of members into the discipline of engineering to inform future funding efforts and evaluation measures of these efforts.

In a volume dedicated to examining the oversights and implicit biases of funding and opportunities in STEM, our goal is to explicate how even well-funded initiatives can have minimal impact if proper attention is not given to core cultural beliefs and practices. Funding directed at promoting equity, diversity, inclusion, and social justice in the engineering academy typically targets addressing the implicit bias within engineering. What we explicate in this chapter is not a ubiquitous critique on all of STEM in higher education. Each discipline manages unique cultures through their membership selection, discourse norms and practices, and reward systems (Schwab, 1978; Traweek, 1990). As such, we limit our critique to three examples of engineering initiatives that have traversed the initial obstacles of recognition and subsequent initial funding which include: identifying limiting factors for undergraduate student support, identifying socializing forces in funded engineering post-doctoral students, and explicitly identifying the cultural capital needed for success among undergraduate engineering students. Our contribution is meant to more carefully examine contributing factors, which can influence the implementation, evaluation, and resulting efficacy of well-intended engineering education reform. Because agencies tend to rely upon the self-report of recipients' success stories for validation, our chapter is a vital account, told from within disciplinary boundaries working with well-intended engineering educators and meant to explore more deeply the implementation and ultimate success of investing in equity. We are researchers embedded in the work and committed to the advancement of equity in engineering education reform. Our critique will help readers and co-workers in the advancement of equity within engineering understand the nature and impact of existing culture on their efforts. Our critique may also secondarily provide funding agencies additional perspectives to re-evaluate their strategies to evaluate the success of funded projects.

We begin by introducing the non-engineer to the state of engineering education equity reform and the minimal impact past funded efforts have made toward changing the landscape of engineering students and practicing engineers. We next explore how structured inequity within the discipline and its representation in higher education diminishes efforts for change. Our chapter brings to bear many voices external to engineering literature to frame explanations of past failures to influence meaningful change. Most of these voices are revered scholars of anthropology, sociology, and cultural studies. We have included one voice as an intended composite of students within the engineering programs we have studied as we believe they are the most ignored, yet most important voices of all. After framing our critique, we offer three actual vignettes extracted from case studies we have conducted to examine two common themes (Table 9.1) which traverse all three funded projects: the definition of engineering identities and the work of engineering faculty.

Table 9.1 The manifestation of the two crosscutting themes of engineering identity and the work of engineering faculty across all three engineering education challenges

	Theme 1 Engineering Identities	Theme 2 Engineering Faculty Work
Challenge #1 Creating awareness Rewarding change	Professors seeing themselves as self-achieving, unaware of the supports and privileges provided to them.	Teaching evaluations and research grants remain the basis for retention and promotion. No explicit rewards nor supports for transformative teaching.
Challenge #2 Reliance upon illusion of support	Engineering students received differential access to requisite knowledge and resources necessary for success.	Post-doctoral work evaluated by traditional scholarship and contributions. New scholars expected to fit into pre-existing work constraints or models of success.
Challenge #3 Explicating cultural capital	First-generation engineering students self-identify, often distancing themselves based on perceiving the cultural practices as foreign.	Some professors remain unconvinced that supporting students outside the classroom is part of their responsibility as faculty.

9.2 Engineering Education Equity Reform

9.2.1 What Have We Learned from 30 Years of Equity Research?

The stark contrast between the general United States (U.S.) population and the representative sample population of engineers in the U.S. has endured through 30 years of alleged reform. In 2014, students who identified as Black or African American earned only 4.2% of engineering Bachelor's degrees, while Latinx students earned only 10.4%. In contrast, Whites and Asians accounted for more than 78% of all U.S. engineering graduates. Women, who hold less than 15% of all engineering positions, also experience vast underrepresentation. Even though research on the dearth of diversity in engineering has revealed large gaps for more than three decades, engineering educators' lack of agreement on strategies to diversify the ranks of engineers (Grier-Reed & Williams-Wengerd, 2018; Long & Mejia, 2016; Rice et al., 2016; Stage et al., 2013) has complicated this context. While studies demonstrate some efforts to increase STEM major choice by underrepresented populations, barriers to retention and degree completion in STEM remain (Moakler Jr & Kim, 2014).

9.2.2 Structural and Systemic Inequity Continues Through Weeder Courses and a Positivist Worldview

An increased understanding of the infrastructure that continues to produce inequities in engineering education, can better equip stakeholders to expand access to education while validating the lived experiences of racially minoritized students

(Henry & Generett, 2005; Huang et al., 2000; McGee, 2015). Systemic racism has disadvantaged students of color from entering and graduating from undergraduate programs, thereby denying the resources necessary for professional success in STEM fields (Fries-Britt & Griffin, 2007; McGee, 2020). Racially minoritized students have varying encounters with racism that can have detrimental psychological, physical, economic, and social consequences. Focusing strictly on the intellectual attainment for these students is insufficient, if we expect students to excel in the meritocracy-based theater of engineering education when they are disadvantaged at entry and excluded upon arrival. Rather, we should ask how might faculty and staff support students of color who exist in a sociopolitical climate with messaging that targets every realm of their existence including social, personal, emotional, and psychological characteristics? For over three decades, strategies to enhance the success of racially minoritized students desiring to major in STEM have focused on strategies such as creating culturally affirming spaces and mentoring (Jackson, 2013; McGee, 2020). However, programs and culturally affirming spaces cannot be effective and efficient until we achieve a more inclusive perspective that critically examines and responds to racist and sexist policies and practices within STEM higher education. Hiring more women and people of color as engineering professors can, in turn, help interrogate the cultural context and assist in producing legitimate academic supports for underrepresented students. However, this is only a partial solution, at best as many scholars are drawing increasing attention to the systemically racist and sexist existing STEM culture faculty are hired into within higher education (Riley, 1999; Riley et al., 2014; Yosso et al., 2009). Efforts to directly address this culture can help members in engineering education environments be more inclusive and develop a sense of belonging for those students traditionally underrepresented in engineering (Armstrong & Jovanovic, 2015; Secules, 2017).

One explanation for the lack of diversity in engineering is the relatively static engineering undergraduate curricula maintained by the majority of research institutions. The engineering disciplines are rooted in a positivist worldview based on the scientific method and focused on facts, laws, and objectivity (Jawitz & Case, 2002). Undergraduates are widely subjected to rigorous “weeder courses” for the first two years (e.g., Calculus 1 and 2, Differential Equations, Physics 1and2, Chemistry 1 and 2) before they are deemed “fit” to engage in real engineering activities. Though many institutions have adopted small “engineering first year” experiences, the vast majority of the curriculum remains unchanged. Students must navigate heavy course loads of highly theoretical, disconnected subject matter isolated from students’ lived experiences and societal concerns (Cumming-Potvin & Currie, 2013). Long ago, researchers in K-12 contexts identified that teachers, who were able to connect social constructivist frameworks with multicultural understanding, enhanced student success (Rodriguez, 1998). The one-size-fits-all model of engineering education practice is largely responsible for the homogeneity in engineering and continues to disadvantage minoritized students. Marginalization of underrepresented undergraduate students transcends efforts to reorganize curricula or tinker with pedagogical approaches. An abundance of evidence demonstrates that White middle-class families provide considerably more support and opportunities in and out of school for navigating abstract classes like calculus and physics and advanced placement courses in preparation for admission to engineering programs. This phenomenon gives already privileged students a leg up in the competitive context of their initial years of engineering (Eastman et al., 2017; Weis et al., 2014). Such disproportionate investment creates an opportunity gap for students without wealthy backgrounds, particularly within urban contexts. Professors often assess students who struggle in their initial years of abstract coursework as unable to be successful in engineering. Framing the issues from a deficit perspective, struggling students are deemed unworthy or unable to continue due to their lack of preparedness from an inequitable K-12 context.

Minoritized underrepresented students who are marginalized, invalidated, and oppressed based on phenotypic characteristics may be more likely than their majority peers to change majors or drop out of school (Miles et al., 2020). The vulnerability of marginalized and oppressed students requires educators to attend to more than their intellect. Racism and its impact on society are documented, yet to provide spaces that validate minoritized students we must provide truth to the lived experiences of these students. For example, students who have contact with their professors both in class and out (e.g., office hours) are more likely to stay connected and to persist during difficult times. Conversely, failing to provide validation can lead to a decrease in academic self-efficacy, which may ultimately lead to dropping out of school or choosing a different major (McGee & Martin, 2011; Rice, 2016; Riley et al., 2014). Drawing on social constructivist principles (Dewey, 1933; von Glasersfeld, 1989; Vygotsky, 1978) and creating educational experiences aligned with the lived experiences of a diverse student body can foster a sense of belonging and empower the voices of underserved students (Rodriguez & Kitchen, 2005; Rodriguez & Morrison, 2019).

9.2.3 Looking in the Mirror: Those Like Us Succeed

The homogeneity of engineering professors and practitioners is anything but accidental. The longstanding White and male culture of engineering has been perpetuated by those who have successfully navigated a system that promotes and rewards orthodoxy and a positivist worldview. Students enter college believing that the teacher's role is to "know The Truth," and the student's role is to absorb that truth and to "repeat it back on assignments and tests" (Felder, 2004; Felder et al., 2011, p. 269). Most engineering education curricula are largely aligned with this rote learning strategy especially in the early years (Cumming-Potvin & Currie, 2013; Jawitz & Case, 2002). In a study of the epistemological beliefs of civil engineering faculty, researchers found an overwhelming commitment to an objective reality that is "meaningful in all contexts" (Montfort et al., 2014). Others have challenged, "faculty members talk at students rather than engaging them in activities that help them to learn and apply core scientific concepts and skills" (Dennin et al., 2017, p. 2). Given this stance, which is counter to honoring individual lived experiences and the tenets of social constructivism, it is no wonder that students who think and act like the faculty member in the front of the room who serves as the knowledge authority are most likely to achieve success in engineering.

In addition to maintaining traditional teaching practices, engineering faculty are rewarded for scholarly accomplishments, including publication in prominent journals as measured by various indices, and by the amount of external funding they can secure. The tenure review process typically defines specific metrics for publication and external funding expectations while leaving teaching expectations much more nebulous. Phrases such as "demonstrate successful teaching," or "demonstrate competency in the classroom," set an extremely low bar for teaching expectations and foster a culture that reinforces mediocrity in the classroom. Although researchers have called for more sophisticated evaluation of classroom learning that includes enhanced student engagement, faculty development, and use of teaching observation protocols (Bradforth et al., 2015), most engineering schools rely on student evaluation of teaching (SET) surveys as the primary means of teaching evaluation. Indeed, research have deemed these ubiquitous tools as "essentially useless" and have mocked the legitimacy of using such surveys by arguing that calculating averages for categorical data in teaching evaluations is "analogous to saying that the average of a pen, peach, eraser, and a piece of paper is a book" (Hornstein, 2017, p. 2). The illegitimacy of such tools is so widely accepted that their results prove ineffective in correcting sub-par teaching (Steele & Aronson, 1998). The result of such practices is that teaching quality is not truly measured, thereby eliminating it as an actual expectation. As educators and researchers, we have personally witnessed overreliance on SET in review of faculty performance and a dearth of any other indicators aimed at evaluating and improving teaching and learning.

Despite the espoused commitment to quality teaching by engineering administrators across the country, the true driver of teaching quality is individual faculty commitment. If we are to influence teaching quality, the propagation of inclusive teaching practices, and the success of a diverse student body, it is incumbent upon university leadership to promote and require teaching practices that encourage deep learning to foster the success of all students. We must reach beyond traditional SET and develop structures to evaluate, require, and reward quality teaching.

9.2.4 How We Frame the Problem Matters: Recruiting More Minoritized Students Without Addressing the Existing Engineering Culture Is Destined to Fail

Making necessary changes to increase cultural diversity among engineers has proven to be an enduring challenge. Hundreds of millions of dollars of student recruitment, training, and support have been directed towards the well-documented attrition and resulting lack of diversity in engineering. The stubbornness of this "problem of diversity" has surprised the field as engineers pride themselves on being accomplished problem solvers. In fact, engineers have a strong reputation of social and civil contributions as problem solvers. Unfortunately, all problem solutions are steered by the original conception of the problem and many have demonstrated how the bias of STEM professionals has led to catastrophic error (Petrosky, 1985). If the problem is ill-conceived, even intentional or non-intentional bias will render the solution ineffective and non-consequential.

One such example of an ill-conceived solution is that of addressing a lack of student cultural diversity through recruitment. For decades, engineering programs devoted increasing university resources to increase cultural diversity in undergraduate programs. The thinking behind such movements was well intended and egalitarian by nature. However, the chosen remedy was insufficient and incomplete. The approach of "treating everyone the same," and offering every student "equality of opportunity for success" has often stemmed from the ill-conceived notion of color blindness (Blickenstaff, 2005; Harper & Patton, 2007). For engineering recruitment, this often translated to bringing more students on campus without removing the student-deficit-oriented solution space, thereby leaving unchecked the engineering culture's existing biases and beliefs about minitorized students.

Torres (2012) documented the increase in underrepresented student participation in undergraduate engineering but no growth in the number of female science faculty at postsecondary institutions. These trends are not surprisingly reflected in faculty retention as well. In one example, Torres described a decade of hiring White males into science and engineering departments for more than three out of every four faculty positions. Similarly, 16% of women faculty typically resigned after 3 years, while only 4% of men departed during the same timeframe. Following this report the institution still received another National Science Foundation (NSF) funded grant to create a new program with similar outcomes despite having refused, according to Torres (2012), to remove existing systems of capitalism, patriarchy, racism, and the normalization of Whiteness. Torres' work and the expanding body of related work in the field demonstrate that without changing the structures, curricula, pedagogy, and assessments, little progress occurs. Existing barriers and structures continue to disadvantage students who do not enter with the cultural capital that majority, White, affluent families provide to their male, STEM-oriented children (Weis et al., 2014). In this way, scholars have argued that inequity should not be conceived as a problem to be solved (Henry & Generett, 2005; Reed et al., 2007). Cultural shifts should also be a goal.

9.3 Changing the Mindset of Engineering Educators

9.3.1 How Can We Shift the Focus from a Student Deficit Model to Supportive Infrastructure Focused on Student Success?

In critique of an educational movement to enhance students' abilities to solve problems, Schön (1983) argued that experts known for their problem solving, in professions such as engineering and the medical field, can rarely identify the sources of their expertise nor are they able to effectively translate to novices how they arrived at their successful conclusion. Schön's ultimate critique identified that engineers are experts at "problem setting" since no expert is ever given a neatly packed problem to be solved. Rather, Schön (1983) argued that experts do not solve problems, they participate in the organization, distillation, and synthesis of a messy world and propose frameworks through which a proposed solution can be evaluated and implemented.

Through this lens, if we are to examine the problem setting that engineers have applied to the problem of diversity, we see that many of the dispositions and beliefs engineers hold regarding insiders and outsiders to the profession, actually render the problem unsolvable for engineering educators hoping to come along-side to assist engineers interested in changing the culture. Take for example the well-documented belief that color-blindness is a solution to equitable access to engineering for minoritized students (Henry & Generett, 2005). It is widely held that this popular stance among engineers is flawed and continues to propagate inequity in recruitment, support, and ultimate completion of a degree (Harper & Patton, 2007; Taylor, 1998). Yet, the solution of equal treatment persists as a potential solution for inequity, despite the lack of evidence to support this commonsense notion (Blickenstaff, 2005). In treating all students, the same, we fail to acknowledge that students have individual, unique capabilities and arrive with different cultural capital. As engineering educators, if we do nothing to explicate some of the hidden or implicit capital some students wield, the same students (e.g., White, male) will continue to be successful, reinforcing the notion that "I did this myself through my own hard work." The process of examining the culture of undergraduate engineering and developing an explicit set of expectations and rules of power for all students assures that, regardless of what capital students arrive with, we can introduce clear expectations and appropriate supports, so all students can succeed.

Another way that engineers arrive at solutions that only exacerbates the problem of diversifying the undergraduate engineering student population is to define differences in successful and unsuccessful students in terms of the intellectual deficits of the students themselves. Many engineering education studies that have examined diversity have only considered program completers as a unit of analysis. Such biased studies may not effectively evaluate the solutions the studies propose. By measuring only, the completers of programs, we effectively obfuscate the opportunity to learn from the lived experiences of those students who were not successful. As such, we may become overly reliant on constructs such as "resilience" which may or may not apply to all students. Measures of resilience reinforce the existence of deficits in those who left engineering. Many deficit characterizations of the exodus of students from engineering appear in engineering education research. Researchers have demonstrated several such assumptions to be without any evidential basis (Blickenstaff, 2005; Reed et al., 2007) stemming from engineers' perceptions of their own identities and preconceived notions of students who can and should complete engineering programs. Unfounded depictions of student deficits are widely accepted including gender differences both biological and cultural, perceived ability, poor family backgrounds, attitudes and early experiences, work ethic, lack of preparation, academic pedigree, and role models (Brainard & Carlin, 1998; Brickhouse, 1994; Carlone & Johnson, 2007). For decades, these false characterizations have concealed the underlying challenges with creating an academic culture that supports the success of all students. Scholars have argued that marginalized students no longer should carry the burden of redefining, resolving, and rectifying the unfair systems that have marginalized them. Rather the system itself should bear more of that burden for resolving systems of inequity (McGee & Martin, 2011; Yosso, 2005).

9.3.2 We Must Listen to and Learn from Those Students Who Have Chosen to Leave Engineering Programs

For nearly a decade, researchers have been exploring the nature of exclusion and structured bias implicit within undergraduate engineering programs at several institutions. Whether examining our own institutions or others who have allowed us to conduct our research, we find proposed many solutions flawed in their characterization of the problem of diversity. Uncritical solutions like targeted recruitment of students allow existing structures to go unexamined and are unlikely to change. Despite decades of research and millions of funding dollars, the graduating seniors look much as they did in the 1960's (NSF, 2013). We believe this is in part due to the screening, blind spots, exclusion, and homogenization of cultural practices and discourse enacted in academic and professional venues. As representative allegory, we have compiled a short anecdote that represents a composite of some of the unwelcomed messages we documented. We frame this as a letter to the Editor of an academic engineering journal from a student, whose voice would not normally be heard because they are departing the program for another major.

> *Dear Editor,*
>
> *I am a student who has recently left the engineering program at my university. Like many before me, I left feeling isolated, unheard, that my presence in class was unrequired, sometimes even invisible as I struggled to keep up. I finally decided for a number of reasons to leave, but I did so with a sense of regret and even a sense that I had failed somehow. Though I am successful in my new major, I am writing you because in my new degree I am studying the mismatch of cultures and what happens when they conflict. Just out of curiosity and alleviating some of my own self-inflicted guilt for the misfit I felt, I searched your journal for some trends, some insights, some answers to why I felt the way I did. What I found after carefully considering the majority of articles published in your journal for the last 10 years, is that the exodus of non-White non-male students is a long-standing precedent. However, most of the articles on this topic seem to focus on issues that I believe prevent researchers from truly understanding the experiences I encountered your contributors to your journal seem to be studying in ways that I believe keep them from the findings I would like to steer them toward. I write you not to criticize their work, only to offer a substantive critique to help direct your fellow researchers to "look outside the box" as they typically think of themselves as problem solvers, and examine carefully some of the assumptions they are making about students like me.*

> *I write you this letter because I have become convinced your readership will never uncover this for themselves. They are too busy measuring their success by examining those who remain and don't leave engineering school—those who your profession call "resilient". If you continue to look only to those who survive the induction, socialization, and domestication processes that occur throughout the initial years of engineering programs (which by the way have changed very little nationally in the last three decades* (Jamieson & Lohmann, 2012) *then you will never truly understand the obstacles students like me face. And what you cannot see, you cannot improve. Several of my friends exited engineering majors before me. Like me, these students left the support of their own communities to come to this engineering school with the hope of achieving success. However, after our arrival, we found that students like us would not be accepted until we conformed to the expectations of our hyper-competitive peers who are continually propped up by the norms of our professors. Those of us who did not fit in, and struggled academically, were informed by our professors "you probably should change majors." My friends told me no one ever taught them the ropes, followed up when they were struggling, nor even asked them why they left engineering. I imagine no one wants to know my story either. Engineering education research journals offer few accounts of researchers ever going back to ask students who have exited engineering majors why they left. It is too much work to follow up methodologically in a research study and your authors are working in academic departments that lack the infrastructure to track those who have left. It is not that faculty think it does not matter. The reality is that there are few, if any, rewards for engineering faculty to engage educational researchers in the social sciences to assist with adequately studying the problem of student attrition. Studying equity fails to match the job expectations for engineering educators at their institutions. So, I write you, as the voice of a student who is leaving engineering—the voice that will seldom be heard and that engineering education research journals are unlikely to explore. I write to you, as yet another traditionally marginalized student in engineering, labeled as being without the necessary preparation or resilience and unworthy of the field, another voice that after this letter will be completely silent and absent from the field. Though engineering literature proclaims to need my voice to strengthen and diversify through a multitude of perspectives, my success is less important than maintaining the existing beliefs about me.*

It is not our expectation that engineering faculty would be predisposed to recognize the biases and barriers integral to the system of producing and socializing engineers. What we would hope from reading such an account is for faculty to ask themselves what they really understand about students who fail their courses and upon what is their understanding based? We would also hope to encourage engineering faculty, along with engineering education journal editors and reviewers to explore how they, themselves, are in part culpable by their beliefs and actions (or inactions) for maintaining a culture that remains impervious to changing the inequity it reflects.

9.4 Reversing Momentum by Addressing Challenges to the Cultural Diversification of Engineering Students

Because of our collective 45 years of experience in engineering education research, we wish to narrow our arguments only to the engineering context of higher education. We are one female and four male STEM education researchers employed at four different institutions who offer undergraduate engineering and who wish to speak to the institutional challenges of making needed changes in higher education. From the perspective of one White and one Indian man engineers, one Black man and one Black woman, both engineering education researchers, and one White male science education researcher, we acknowledge our own biases brought on by our personal experiences, slights, and privileges afforded to us in our individual journeys as higher education professionals. At the same time, we tell our accounts of successfully funded STEM initiatives intended to make substantive improvements that may be influenced by institutional inertia, intentional and unintentional race and gendered bias, and structured inequity in the institutions we have studied as well as the places where we work. We attempt in this chapter to examine three critical incidents aimed at moving the needle through funding equity and social justice efforts in higher education to illuminate to better use spending to accommodate lasting change. We draw from the scholarship of other disciplines (e.g., sociology) to frame our assessment and recommendations. It is our hope that members of the engineering field consider equity voices and scholarship that transcends the normal reading consumption of engineering faculty who teach our undergraduate students but are necessarily driven to technical, discipline-focused research.

In line with the explicitly stated goals for engineering education leadership of the American Society for Engineering Education (ASEE), we seek ways to contribute to the understanding of how and why changes in the culture of engineering have been so slow and how they may be accelerated. We share Jamieson and Lohmann's (2012) goal to support efforts towards "creating and sustaining an engineering academic culture that encourages and supports educational innovations with impact…" (p. 16). More specifically, we hope to improve engineering education research that informs the culture of engineering education and the context surrounding instruction to "make engineering programs more engaging and relevant, while enhancing efforts on making engineering education more welcoming" (p. 7).

From our research and the countless cases that have confronted us in our own engineering programs, we are convinced more than ever that opportunities exist within the funded efforts we pursue and the departmental budgets we create to capitalize on existing diversity movements and welcome new perspectives to transform engineering culture to be more accepting of diversity. We aim to find new ways to think about how we might promote and sustain the participation of underrepresented undergraduate students in engineering. To this end, we present three challenges through vignettes, drawn from our own data collection while analyzing higher education culture over the last 10 years and unpack crosscutting themes that traverse these vignettes (Table 9.1). We address issues related to faculty dispositions and beliefs, the role of race in exclusion, and the explication of cultural capital. These challenges depicted among these vignettes include creating awareness and rewarding change, reliance on the illusion of support, and making explicit the cultural capital required for success. Through each of these vignettes, we explore potential ways to establish new strategies for conceptualizing success at these different institutions.

9.4.1 Vignette #1: Fighting Against the Status Quo and Rewarding Faculty for Inclusive Pedagogical Strategies

Midwest Technical University (MTU) is nestled in an urban context that experienced significant economic downturn in the 1970s. Since then, manufacturing jobs left and the city has become one of the most impoverished in the country. Along with a failing economy came under-resourced and failing schools, particularly in the urban settings. In the local urban district 15 schools have been categorized as "failing," with five of those designated a failing for 10 consecutive years. Additionally, in the 2015 Failing Schools Report published by New York State, only 2% of the teachers in this district received "highly effective" ratings, while 41.9% of teachers across the state received that rating. Despite the close proximity between campus and urban school district, many MTU faculty had never deeply considered the stark disparity between the high school experiences of the students enrolled at their university and those students from the urban school district in their own backyard (Eastman et al., 2017).

One approach to funding a change in diversity in engineering is investment in "seed projects" for building institutional capacity. Many institutions seek NSF funding to make a change in the culture or even "revolutionizing" engineering departments (NSF, 2019). The Dean of the College of Applied Science at MTU desired to raise the status of his college, develop a reliable external funding mechanism, and become a leader in STEM education research. To increase the capabilities of his faculty and to build a foundation of education research, the Dean invested in a dozen faculty to enroll in an education research focused PhD program. Approximately a dozen engineering faculty from MTU enrolled in this doctoral program. Within 5 years, six MTU faculty members had completed graduate degrees and had begun to push for meaningful changes related to pedagogy and research at their own university. Though it was not his original intention, this growth of knowledge in his faculty resulted in a collective movement to raise awareness about diversity and to make their institution and STEM programs more equitable. Their experiences in the doctoral program led them to realize that, consistent with most engineering faculty, they had never been properly educated in the theories of teaching and learning, nor had they engaged with the extant education research. After completing their doctoral degrees, these long-time faculty members enthusiastically embraced goals to address inequity at their own institution and make a difference in higher education. It did not take long for these educators to recognize that the barriers of entrenched beliefs and long-held structural practices would be difficult to overcome.

After completing their graduate degrees, this team of engineering educators began to engage in two research pathways including analyzing the local engineering education culture and advocating at their university for inclusive pedagogical strategies, those that address intersection identities and eschew the assumption that there is a normal baseline student. They sought to build a coalition of willing participants by collaborating with those faculty most interested in supporting pedagogical change. Because of their status as recently minted PhDs, MTU regularly provided forums to share their experiences with their colleagues. However, while engaging in those conversations the advocates for student success regularly encountered apathy and in some cases galvanized resistance. While they were able to identify a small number of willing and sympathetic colleagues, they initially found faculty at their home institution had little interest in enhancing diversity or adopting inclusive teaching strategies. In an attempt to advocate for students, these MTU faculty who were recent doctoral graduates argued for more relevant curricula, more engaging pedagogy, and to connect abstract concepts with real world examples to promote student success. Such suggestions often elicited responses from their peers such as "my job isn't to make it easier for students, my job is to ensure our graduates are prepared for industry," or "the breakdown is in the urban school system, we can't help the students they give us." Although university leadership made money available to support pedagogical changes, some faculty clung to a student-deficit orientation and the traditional excuses of bad parenting, incapable students, and protecting the discipline as a means of retaining the structures that permitted engineering to remain among the most homogeneous of disciplines.

This team of engineering educators took it upon themselves to explore the structures of engineering education culture continue to prevent students from under-resourced urban areas from achieving success in engineering and other STEM disciplines. Their research at MTU found that many STEM faculty had little connection to or understanding of their surrounding urban school district and lacked a widespread commitment to removing barriers to success for minoritized students (Eastman et al., 2017). Eventually, they were able to identify opportunities for building a more culturally inclusive environment within the classrooms of their college. Pockets of faculty at MTU have begun to adopt inclusive pedagogical strategies and have moved away from traditional lectures. The newly appointed Dean of their home college now focuses on student success. He has supported workshops for improving classroom instruction and provided seed money for teams of faculty to redesign courses to support a more diverse spectrum of learners. In one year, faculty in the Applied Science College at MTU modified nine courses to include research-based pedagogical strategies supported by science education research (Rodriguez & Kitchen, 2005). The revision of nine engineering courses is a meaningful start. However, MTU offers over a hundred different engineering-related courses each year, and there is still much work to accomplish in creating a nurturing environment for all students. The MTU faculty who completed graduate degrees in STEM education research continue to advocate for culturally diverse students and understand that changing culture is a painstakingly slow process.

9.4.2 *Vignette #2 Focusing on the Long-Term Success of Graduate Candidates*

Many research-intensive institutions heavily rely on the labor of doctoral students and postdocs to maintain their research enterprise. Diversity initiatives are often tied to supporting STEM research efforts by recruiting underrepresented postdoctoral researchers. Institutions practice cluster hiring to create a network of colleagues to support one another in diversity practices, increase productivity, provide a micro culture of inclusivity, and increase retention. The hope is to support a diverse faculty pool to minimize the often-observed isolation of faculty of color and increase the intensity of the messages for change through solidarity. Some institutions have adopted this approach for grooming future faculty members of color through “clustering” postdoctoral scholars preparing for their entry into higher education. Such was the case for the principal investigator of the federally funded Engineering Education Diversity Cohort (EEDC) at Southeastern University (pseudonym). Southeastern University’s (SEU) efforts to concentrate resources, training, mentorship, and research behind a cluster of underrepresented engineering education postdocs achieved limited success. The postdocs received mentoring and professional development. However, the fellowship’s objective of assisting the postdocs with securing a tenure track lines did not occur. Despite the powerful mentoring the postdoc cohort received, the strategy failed to increase hire rates of junior faculty of color in STEM. Southeastern University received federal funding for a cohort cluster hire of underrepresented postdocs, hired under the president’s new diversity initiative. These highly qualified and nationally awarded recent doctoral graduates embarked on a three-year postdoc position to be “groomed” specifically for tenure-track positions at the host institution. Despite best practices for ensuring success support such as individual mentoring teams, research and professional development funding, and a cohort structure, this fellowship did not achieve the desired results.

Though the support in this program was robust, the implementation by the faculty varied. The faculty and leadership implementing the fellowship was not properly prepared to provide support for a diverse cadre of postdocs. As an example, one of the post-docs in the diversity cohort was a White male engineer in a wheelchair, who designed many devices prior to coming to the institution. Though capable, knowledgeable, and qualified, he would never actually gain full access to the laboratory, which he was promised. His faculty advisor was unaccustomed to working with non-able-bodied postdocs and attributed the postdoc’s disability to an inability to engage in engineering, which was clearly not the case. After lodging several complaints to the fellowship committee and the academic department, the postdoc felt it was no longer worth the fight required to prove his ability. He was already nationally acclaimed; he cut ties with the university and entered into the workforce. He is now thriving in the role of an entrepreneur in the private sector.

In a different example, the fellowship failed to provide support for a Latino engineering postdoc when he found was trying to gain more teaching experience to build a competitive CV. He attributed the challenges he encountered to his ethnicity, which contrasted the White male student population. He would often share “they [faculty] just don’t know what to do with me.” He endured being excluded and experiencing toxic and racist interactions in the computer engineering department. This postdoc also filed complaints through the appropriate channels. Like those of the White male, his concerns were not taken seriously. Colleagues offered little consolation with statements such as “that is just how [the faculty here] are.” The university had little or no infrastructure to assist faculty with reflection on their relationships and interactions with postdocs.

Postdocs received no institutional protection from the numerous counts of physical and mental abuse they endured at the hands of faculty. The stakes were high for postdocs if the mentoring faculty member or grant principal investigator did not cultivate inclusive environments. For this particular diversity postdoc fellowship program, none of six postdocs received a tenure track position at the host institution, three left the academy, one took a lecturer appointment where teaching and student engagement was more valued, one remained in a laboratory, and one took a tenure track position at a different institution. Of this cohort recruited into these postdoc positions, only 16% landed tenure track positions in higher education. Though all post-docs had nationally competitive CVs, knowledge, experience, and success trajectories, their current relevant experiences in higher education impacted their career choices the most heavily. They were strong, competent, and knowledgeable doctoral candidates of color who were dissuaded from a tenure-track trajectory. This account demonstrates the importance having clear paths of entry into the profession, and responding to the needs of a diverse cohort, in addition to the training faculty and providing professional development to potential mentors for candidates of diversity initiatives.

9.4.3 Vignette #3 Making Explicit the Cultural Capital Required for Success

There are unexamined assumptions that surround the debate over student success. In mathematics, there is a reported prevalence of instructors that believe mathematical abilities are innate. One has them or they do not (Heyder et al., 2020; Schwartz, 1995). Engineers often attribute student success to work ethic (Christman & Yerrick, 2017; Conefrey, 2001). A characterization of the evidence of engineers' beliefs found in these studies is typified by engineering faculty professing, "If the students would just work harder, they could succeed." Apple (2020) argued that students' school success is heavily influenced by the students' ability to transfer relevant experiences, knowledge, and skills as well as the mannerisms and discourse of their prior culture into one of an academic context. Apple invoked Bourdieu's (1975) notion of "cultural capital" to describe how an individual's social status and cultural similarity could advantage majority students over minoritized students and lead to a cultural gap in achievement.

There are examples of institutions taking stock of their students' incoming attributes and cultural capital and leveraging them for maximum success for all students. North Carolina Agriculture and Technical State University (NCAT) is one such engineering program, which has built upon its legacy of exemplary teaching and scholarship as an Historically Black College and University (HBCU). Currently, NCAT graduates the largest number of African Americans undergraduates in both engineering and agriculture in the nation. They accomplished this by living up to its explicit commitment to recognize, enhance and expand the knowledge, skills, and dispositions of incoming students. From its inception, NCAT set a course for valuing and leveraging the unique attributes of incoming freshman toward their eventual academic success though advising, academic supports, career development, research opportunities and community/professional experiences.

Other institutions also have adopted a stance of recognizing and leveraging the assets freshmen bring with them in order to help acclimate and support them through to their graduation. Western University (WU) is one of those schools. The leadership of the College of Engineering at Western University was in search of ways to increase their retention and graduation of undergraduate engineers among a population of students who were 56% First Generation (FG) students. The additional struggles of FG are well documented and they often have higher dropout rates and student loan defaults than any other university student population independent of majors (Britt et al., 2016). With the additional challenges that highly selective fields like engineering pose to undergraduates, the Dean of the engineering college was in search of solutions which could traverse a variety of student groups who were represented a spectrum of linguistic, gender, and cultural diversities of Central California. After examining the practices of successful graduates, alumni, and local practicing engineers, it became clear that there was a pattern of experiences, practices, and events, which some students of recognized incoming privilege all had in common. These students shared a collection of cultural capital and implicit values exhibited through shared practices. The Dean and his faculty identified more than two dozen common practices including: creating a resume, seeking academic assistance, checking in with advisors, introducing oneself to future employers, attendance at career fairs, application for internships, and other similar landmarks. The general understanding of the faculty was that these common practices were a part of the cultural capital that some students brought with them but others did not. Since most of the students came from a demographic where fewer than 20% of the population achieved a Bachelor's degree, the challenge was to find a way to share the requisite capital with all students, not just the affluent few. Their first step as a college was to identify these important cultural practices, which were common among successful engineers, and to compile an advising sheet for distribution to all students to guide them. Making these a common practice for all students was a more challenging task as this "one sheet", as it became affectionately known, needed to be enacted through both their advisors as well as corporate mentors who would eventually offer these students professional internships. In consulting the mentoring literature, the Dean drew upon a model of mentoring that did not cater to just one kind of student demography. His belief was that every student would benefit from a mentoring program and intentionally prescribing these events. The literature on mentoring suggests that mentees experience enhanced self-esteem and exhibit improved professional competencies when professionals in the field mentor fledgling engineers. To provide clear expectations for all, the Dean created a mentoring framework, timeline, and mentoring expectations. The explicit message from instructors and mentors all the way up to the Dean's office was,

> This program is hard. It is not just hard for you, but it is hard for everybody. There is a reason, for you to accomplish difficult things within your degree. Engineering is job that is complex and the profession needs you to be a good engineer, construction manager, or whatever this degree takes you to in your work later in life. There are explicit ways you can cope with this challenge. Mentors will share, with you how they did it as a student and how you can use your academic and professional experiences to succeed in the field. (Internal communication with author)

Within a year, the school of engineering had received commitments from more than 150 mentors who were recent alumni of the college (<10 years). Program leaders matched mentors with mentees, as much as possible, based upon gender and major. The Dean stated, "We began with gender matching as it is so vital in literature and their majors. Mentors were well known by the school but incoming freshmen were known only by their self-disclosed incoming information so there was guesswork required for more cultural or linguistic matches." More than 400 students were enrolled in the formal mentoring process, where mentors met with their assigned mentees three or more times per semester to review a prepared checklist. Most mentors exceed this meeting frequency and all incoming engineering students.

Some engineering departments had more focused efforts than others had, and prepared recorded messages from Student Services and broadcast encouraging messages from the Chairs and Dean to convey their commitment to the success of all students. Although no faculty in the college of engineering have openly opposed this approach, there exists a minority of engineering faculty who have not fully embraced this mentoring program. When asked, the Dean described these faculty as "representing a more traditional approach, evaluating their own value as faculty from a narrowly constructed identity and limiting themselves by means of external funding to only teaching a few select classes." He explained, "Because of limited time, they are often so focused on their teaching, research and scholarship or even more narrowly on the constructs of their discipline (e.g., water, transportation, construction) that they defer the responsibility of broader student success to others," and added "even though they may have great influence in the overall student success." Unwavering from his commitment, the Dean described future intentions to work more closely with these faculty members to enhance the culture for all students.

Though initial evidence is limited, new conversations about student success are beginning to occur and that momentum continues to build as enthusiastic mentors expand the pool of mentors by recruiting new alumni. Early indicators reveal that first-year retention has increased over prior years and interactions between mentors and mentees has increased student performance. The Dean's recognition that propagating the behaviors of a small and predictable group of students signaled an opportunity to scaffold support and success for all students has led to measurable results. For first generation students, this mentor program made the rules of power and access to success more predictable as researchers have argued (Delpit, 1988;Ladson-Billings & Tate, 2016) that rules of power are rarely made explicit. Yet through this effort, a much larger percentage of students have the probability to be successful.

This Dean is hopeful that mentoring programs will level the playing field by making explicit the cultural capital for all students and that engineering programs can more systemically provide guidance and support for success beyond a privileged few.

9.5 The Problem of Change Within Engineering

Our experience has been, when left to work alone to increase cultural diversity among their students, engineering faculty often resolve the problem of diversity by finding ways to frame a solution around the perceived deficits of students. Rather than placing the solution outside of engineering faculty members' sphere of influence, we offer another lens. We believe the past framing of the problem places engineering faculty in falsely objective positions on the periphery, outside the problem. We posit that this is likely the reason there has been minimal progress in enhancing the cultural diversity among engineers. We believe it necessary to change in the culture of engineering in higher education. We align ourselves with Jawitz and Case (2002) who argued that "instead of the traditional activities which try to persuade [outsiders] that they should try engineering and then help them fit into the culture ... we need to create a new engineering culture" (p. 390).

There is no question about the demonstrated dearth of Black and Brown faculty, staff, and students in engineering colleges across the country and that this lack makes it difficult for prospective faculty members to see these institutions as a welcoming new home. We see in each of these above examples a resistance to change and evidence of a dominant culture that is not ready to fully receive and support new ways of thinking. Universities spending money to recruit students and faculty of color does not directly translate to vibrant, productive, and diverse communities. The recruitment, selection, and hiring practices of minoritized faculty are just three filters which demonstrate the need for cultural change in higher education. Most Primarily White Institutions (PWIs) have stated missions for inclusion and some have documented plans to increase underrepresented students, faculty, and staff on their websites. Diversity training, aimed at eliminating bias and creating fair hiring practices, is often required of most faculty and staff search committees. Universities have created positions such as chief diversity officers and leaders to increase faculty and staff diversity and recruitment and some universities have created programs to build relationships with newly minted, underrepresented doctoral candidates (Baker, 2010; McGee & Martin, 2011). Despite these efforts, barriers to diversifying PWIs still prove challenging to overcome. Search committees, despite best intentions, retain their cultural biases and those from the dominant culture continue to bubble to the top.

9.6 Learning from Our Experiences: Understanding the Resilient Cultural Norms of Engineering Education

Having described above the culture of engineering and some of the challenges facing these three unique engineering programs who desire to enhance cultural diversity on their campuses, we want to now speak to some crosscutting themes revealed in the vignettes, which we believe dampen or hinder the best efforts to fund change in the culture of engineering.

9.6.1 Crosscutting Theme #1: Engineers' Identities Are Developed Within Insular Environments That Limit Engineers' Propensity to Reflect Upon Their Own Biased Views of the World

Engineering students are an elite group. Extant research has demonstrated that this group is socialized in highly competitive learning environments, which have been found to favor the success of men over women. In contrast, several have argued for more collaborative learning environments to reverse the trend of attrition among minoritized students (McGee, 2016). Researchers have identified competition as a likely reason for attrition from this college major (Eisenhart et al., 1996; Seymour & Hewitt, 1997; Tobias, 1990) Enacted within college STEM classrooms Tobias (1990) posits, "[STEM instructors] continue to expect the next generation of science workers to rise, as they have, like cream to the top. This is why introductory college courses remain unapologetically competitive, selective and intimidating" (p. 9).

The argument of maintaining high standards through high attrition rates allows engineering faculty to rely on their own beliefs, which are reinforced within their own experiences and shape their collective and individual identities. Because of their self-reinforcing belief systems, Blickenstaff (2005) argued engineers are able to deflect and maintain externally focused explanations for the lack of diversity of engineers including biological differences, poor student attitudes, and absence of role models. Each of these explanations have been debunked and shown baseless from available evidence yet are accepted as common knowledge among many practicing engineering faculty (Blickenstaff, 2005). In Vignette 1, the MTU Dean intentionally created context and provided fiscal and other resources for changing the cultural climate of the engineering school. Though it took several years, many of his faculty examined their beliefs, isolation, and privilege and took steps to examine the cultural climate towards underrepresented students. They evaluated funding opportunities for local underrepresented students to attend MTU, and set goals to revise the pedagogical approaches to instruction to be more responsive to a broader representation of MTU students (Eastman et al., 2017, 2019). Yet the investment in a relatively small group of faculty, without fully engaging the remaining faculty, was met with cultural inertia, which stifled progress. In a similar way, SEU faculty exhibited in Vignette 2 were unable to see beyond their own values for what was a desirable and acceptable experience for engineering post-docs. The instantiation of "Ableism bias" impaired the access of students and beliefs about what counted as valuable experiences in the profession steered another student away from their passion toward excellent teaching and toward their internal bias of objective research. In similar ways and over many years, WU exhibited engineer belief bias in consistently fostering a culture that supported the success of only a certain type of student. It was the recognition of the outcomes and the interrogation of the context that led to explicating the goals that could help all students succeed. Most faculty were willing to follow the efforts of the Dean to look outside of the higher education context, and beyond the internal focus of existing engineering faculty to solicit advice from practicing engineers and alumni who understood the program from an outsider's perspective. Although a small cadre of faculty still maintained traditional norms and did not fully embrace the mentoring program, most faculty were able to accept the critique of outsiders and agree to support incoming engineering students in new ways. This acceptance was instrumental in for the success of 54% First Generation students.

The theme of addressing engineering insular identities and expanding beyond unexamined biases and identity can be a useful tool for examining teaching, funded programs, and retention. This theme could also be helpful in identifying more clearly the source of attrition in the pipeline of engineers. If we could engage engineers in a discussion of latent beliefs and assumptions about cultural diversity, there would be fewer instances of blaming incoming students or the K-12 instruction, which preceded their application to universities. Instead, we would recognize that heavy student attrition occurs in the first 18 months of undergraduate engineering exposure. For example, the general U.S. public was alarmed by this disparity, public schools responded through curricular and pedagogical innovation to close the "opportunity gap" created within the context of schooling rather than trying to "fix" the population (Baker, 2010). Data reveals that over the last four decades, girls have consistently made gains to close the gap in K-12 math and science achievement (Scafidi & Bui, 2010). Girls are now graduating from high school having taken equal numbers of math and science credits and earning higher grades in those subjects than their male classmates. Additionally, girls have shown comparable success in Advanced Placement courses, have as strong of a grade point average, and are equally likely to select a STEM field of study in undergraduate education (Baker, 2010; Kahle, 2004). Despite such gains, within three semesters of undergraduate engineering prerequisites and courses students within engineering majors remain more than 85% White and male. If science education research can impact K-12 education to increase female students' success in AP science classes, GPA, and STEM major selection, there should be no reason this progress cannot also impact higher education trends.

9.6.2 Crosscutting Theme 2: Changing Engineering Faculty's Definitions of Work Implies Rewards and Consequences

We pose the question, "What is the nature of the work of engineering faculty in higher education?" We wish to answer beyond the clichés of common wisdom like "expanding students' minds" or "preparing the problem solvers of tomorrow". Instead, we look to the rewards and existing practices to observe the enacted definitions of work. Universities promote three pillars of faculty engagement and responsibility: teaching, research, and service, which are the main staples of faculty expectations and annual evaluations. The competitive landscape posits university faculty rewards primarily for research, acquisition of external funding, and publications. Individual universities extract millions of dollars every year from government entities such as the National Science Foundation (NSF) and the National Institute of Health (NIH), in addition to securing funds through private organizations to promote specific research projects. Securing funds and generating publications brings accolades to universities, provides fodder for annual reports and glossy marketing materials. To evaluate faculty research, universities generally establish prescriptive practices that enable them to quantify accomplishments in terms of external funding dollars, number of publications, and value indices such as the H-Index or other forms of measuring the value of faculty publications (see https://researchguides.uic.edu/if/yourimpact).

The evaluation of teaching, however, is typically much less rigorous and does not generally follow "best practices in the literature" (Pitterson et al., 2016, p. 5). Although unintentional, these rewards distract undergraduate faculty from focusing on quality classroom instruction. Literature is replete with accusations that student evaluations of teaching (SET) are an insufficient means of understanding teaching quality (Hornstein, 2017). While nearly all universities use SET to measure faculty's instructional practices, they avoid regular, holistic approaches to teaching evaluation that would enable a complete assessment of teaching because they are time consuming and require a deep understanding of teaching and learning that is simply not ubiquitous across the landscape of higher education.

Few engineering faculty have enrolled in pedagogical courses offered by their own colleges of education. Few, if any, engineers claim to be pedagogical experts and the vast majority report that they "teach the way they have been taught." Pedagogical re-orientation and re-imagining requires serious investment–particularly when bias, inequity and challenges to equity and objectivity are at stake. Rather than take on the additional work and the burden of rethinking instructional design, approaches to dealing with struggling students include remediating, counseling students out of the major, or simply advising them to work harder. Scholars have critiqued these responses as not fully considering other contributing factors (Bastalich et al., 2007; Jawitz & Case, 2002; Martorell & McFarlin, 2011; Riley et al., 2009; Tobias, 1990). Such orientation presumes that if students work harder, they will be successful; a perspective often held by professors who resiliently resist alternative educational frameworks (Jawitz & Case, 2002). We argue that engineering administrators should consider pedagogical excellence a central engineering faculty expectation. This is particularly relevant in a context where student deficits are blamed for low retention rates. Pointing to role models as a solution does not solve the problem according to Bastalich et al. (2007). Rather, they redefined these diversity issues as,

> a problem with engineering…workplace culture [which] polices a narrow set of masculine norms and is intolerant of diversity...[members] who fail to conform to strict codes of [White] masculine conduct, are cast as an 'outsiders' or 'foreigners'...There is a need to find a new kind of engineering image, one in which professional values, ethics and sensitivity to the effects of engineering outcomes in the world at large are emphasized (p. 397).

We interpret Bastalich and colleagues to be saying that masculine and positivist and other biased norms do not constitute the whole of what should be counted as the work of engineers. Beddoes and Borrego (2011) have made a very clear case for the usefulness of alternative frameworks through which to view eingineering education contributions.

We see in Vignette 1 the example of MTU having success that shifting the implicit bias of engineering instructors is possible, at least for a collective few. Faculty at MTU continue to explore their instruction and the beliefs that drive pedagogical change identified by recent education reform initiatives. However, Vignette 1 also illuminates that working against entrenched cultural norms is a slow and often frustrating process. The new Dean at MTU provided faculty a level of encouragement and support that led to a modest transition of teaching and learning strategies demonstrated to support a diverse student body. Many questions remain about how to influence broad and meaningful change in the teaching and learning culture of engineering.

We observed in Vignette 2 that SEU leaders promoted supports for diversity and included benchmarks for increasing diversity, graduation rates, and student achievement in their strategic plans. If these stated measures remain only rhetorical and not translated directly into faculty actions, it may fail to override the unquenchable thirst for external funding and research dollars at the sake of creating an actual increase in the number of faculty of color hired into tenure track engineering education positions. Several scholars are pointing toward "grow-your- own models" which are claimed to be effective for preparing individuals to be successful faculty members within higher education. While the cohort postdoctoral models are very beneficial for the institution and the individual, clearer plans and deeper commitment are necessary to raise up these individuals beyond their present status. As managers can be supplied specific knowledge to rise through the ranks, so can postdoctoral candidates. This will concretely lead to individuals who can contribute to their fields in ways that address issues of equity and diversity.

Meaningful change in teaching engineering requires not only explicit support structures such as the mentoring program demonstrated in Vignette 3, but WU faculty also needed to adopt a stance recognizing student individual needs. Decades ago, the kinds of equality and color-blindness solutions that were a "one-size fits all / treat everyone the same" were acceptable. The strongest survived and those survivors were sufficient for advancing the engineering needs of the United States. Walls (2015) argued such practices of addressing diversity in higher education only rendered race to be neutral under such a colorblind ideology (Harper & Patton, 2007; Taylor, 1998) which in turn helps preserve the homogeneity of the discipline. To mitigate the influences of higher education's current search practices, we must recognize the value of diversity and actually *count* that diversity in our search process. Until we do so, we will continue to perpetuate the systems of exclusion and oppression that created the homogenous culture of engineering education. Today, a colonial approach to education cannot survive because we need more, and more diverse, engineering minds to solve the unique and mounting challenges that confront our global society. WU faculty are becoming more aware of their students' strengths, attributes, and needs, and faculty are becoming more engaged with the students as a result of paying close attention to specific professional competencies as well that the mentors are supporting. However, there has been no real change to the evaluation of instruction at WU. There are no real measures of growth in place to gather necessary evidence to examine clearly any causation versus correlation for invoked changes and subsequent outcomes.

9.7 Providing Hope and Believing That Change Is Possible

It is time for us, as engineering faculty, to see our students as individuals with unique needs. We must move beyond only support structures designed to enhance intellectual prowess so that minoritized students can succeed in traditional engineering classrooms. Focusing solely on increasing undergraduate engineering students' aptitudes has yielded little progress. Moreover, we must move toward holistic educational strategies intended to nurture students, to build their confidence, and to help them understand what they do not. To accomplish this, we must first examine the culture and enacted beliefs of our own profession. Only then can we know the lived experiences of our students and learn who they are, and connect with them personally and intellectually.

The work ahead of us is neither simple nor comfortable. Many engineers prefer the traditional, disconnected culture of engineering education that permits faculty to profess and requires students to meet rigid and antiquated expectations, which do not necessarily demonstrate comprehension, or leave the academy. We as faculty in higher education cannot continue to prioritize research and external funding over undergraduate teaching and learning if we want to influence broad change. We cannot continue to promote teaching strategies that focus on silos of information delivered in a detached, non-contextual manner, which rely on a body of homogenously-prepared recipients who are ready to listen and regurgitate information. To bring about a new culture in engineering education that places a primacy on students as individuals and requires willing and capable faculty and administrators. We must also ask ourselves difficult questions related to institutional priorities and how we choose to measure our own success.

To shift the traditional engineering culture to an environment truly focused on the success of a diverse body of learners and to promote inclusive teaching practices in higher education, we must first educate our faculty in quality teaching and inclusive teaching practices and we must continue to reinforce expectations for quality teaching. We must systematize inclusive teaching practices across engineering departments and put in place new to requirements to measure the fidelity of such changes in curriculum and instruction. This includes adopting strategic and measured intentional interactions between faculty and students promoting a shared understanding of the undergraduate engineering context for both students and faculty. Universities should require teaching-focused professional development in the on-boarding process, during the pre-tenure stage, and throughout the careers of all faculty who teach students.

The burden of welcoming minoritized faculty and students does not only fall on the shoulders of engineering faculty. In order to change the expectations of the profession, we need administrators willing to take risks and ready to challenge the status quo of academia. Administration often describe the need to gain faculty "buy-in" and this is true. However, we also need to look at how faculty engage in the process of adopting inclusive practices and understanding their role and advocacy in the process. Administrators should consider expectations, rewards, and consequences to persuade faculty to act otherwise. There exists a wide spectrum of types of faculty, and effective administrators must understand how to motivate them all toward equity goals.

The ample extant research explicates that traditional engineering instruction is in desperate need of change. Literature is replete with examples of research-driven pedagogical changes resulting in a variety of desirable academic outcomes, accompanied by the stemming of the hegemonic practices and severe student attrition associated with the traditional culture of engineering. Thoughtful solutions are available. Change is necessary. What is required is a committed and reflective faculty workforce in engineering education who wish to enact the practices engineering education reforms demand.

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Chapter 10
"*What Have You Done for Me Lately*": An Afterword

Terrell R. Morton

> *Your friends seem to think that you're so peachy-keen. But my friends say neglect is on your mind…Who's right?*

In 1986, singer, songwriter, and performer Janet Jackson released a song titled "What Have You Done for Me Lately." This song, co-written by James "Jimmy Jam" Harris III and Terry Lewis was featured on Janet's Album, *Control*. In the song, Janet conveys her frustrations with navigating what I would name as a toxic a relationship. This toxic relationship is one where Janet's partner, someone who at first presented their self as being in love with her and would go all out for her now 'gas-lights' her, takes advantage of her, and makes it seem like anything she brings up as a need or challenge is her problem or her fault and not theirs. The main question of the song, "what have you done for me lately" represents Janet's "awakening" to the fact that the relationship is toxic, that she deserves better, and that she is no longer going to tolerate subpar treatment.

I titled this afterword after the song and use its lyrics as the introduction for multiple reasons. One, I love R&B as a music genre. As a musician, I always find ways to engage the Arts within my thinking, theorizing, writing, and sharing. In a lot of ways, music functions as a world language that many across the globe can "understand," "speak," and engage. Music thus provides the space in which thoughts and ideas can be conveyed in ways that words, alone, cannot. Second, the message of this song perfectly articulates the core argument reflected across the chapters in this edited volume. That core argument is the incessant juxtaposition between the presentations of investments in equity and inclusion endeavors across the STEM education and workforce ecosystem and the manifestation of those investments that

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minimally impact if not perpetuate oppression. Janet's expressed frustration with gas-lighting in her relationship is a similar frustration that people who have been historically and contemporarily excluded and marginalized share with institutions and other structures that hallmark diversity, equity, and inclusion (DEI) in STEM education. And the frustration is not just for the learners, students, participants who engage these spaces; it is also felt and communicated by the faculty, staff, educators, scholars, families, and communities intimately involved with trying to dismantle structural oppression and facilitate spaces in which the targeted can be whole.

Across the chapters, the authors outlined localized and societal manifestations of structural oppression uniquely connected to the diversity, equity, and inclusion in STEM education enterprise. These manifestations primarily occurred through constrained (or lack of) funding and the prevention of broad scale dissemination through publication. They also manifested through deficit-oriented, colonized mindsets and enacted beliefs by various players within the STEM ecosystem. And while each author or set of authors shared their perspective as to why funding, dissemination, and mindsets functioned as structural hinderances, across the chapters I see a shared underlying issue…the cultural norms, values, and beliefs associated with STEM, STEM education, and the knowledge generation and dissemination process.

The culture of STEM and STEM education, being rooted in hegemonic, western Eurocentric ideologies (i.e., conceptions of reality, truth, knowledge, ethics, processes and procedures, and beingness that center, privilege and favor western, Eurocentric perspectives of life) govern DEI endeavors and possibilities. Hegemonic, western, Eurocentric ideologies are presented as (and are expected to be) standard, normal, and universal. Generalist assumptions of universality prompts the same standards of success that DEI attempts to challenge as being the metric by which DEI endeavors are measured. These standards and metrics thereby facilitate the assumed norms associated with "quality," "efficacy," and "merit;" perspectives that deemed a lot of the work discussed in this edited volume as ill-fitting, not qualified, or not robust enough for access to sustained, significant funding or traditional dissemination processes as noted by the authors. These same ideologies served as the foundation for the mindsets and beliefs espoused by the STEM educators, STEM faculty, and institutional administrators who also played roles in attempting to constrain the access and outcomes of the work presented in this edited volume.

The juxtaposition of "talking DEI" to "walking DEI" (i.e., talking the talk versus walking the walk) and the frustrations resulting of it is not a new phenomenon. People historically and contemporarily excluded and marginalized experience the outcomes of this tug-a-war and have been communicating their frustrations for decades. Yet, funding agencies, academic and lay journals, and even institutions have failed to truly and effectively listen to what these groups have decried; they have also failed at putting forth real efforts to address the root causes of the problem. Personally, I believe that the failure to address the root causes is multifold, one reason being the failure to actually see the roots because of the lack of actually believing these groups and embracing their various collective standpoints.

In a lot of my work, I discuss the experiences of Black women and Black students studying STEM at the postsecondary level (see https://linktr.ee/Mortontr). To unpack the relationship between how they see and understand themselves compared with how the external environment attempts to regulate and control their experiences, I draw from Phenological Variant Ecological Systems Theory (Spencer, 2006). This theory highlights the intimate relationship between the self and the external environment, and how both influence each other and people's outcomes. In using this theory, I note student experiences within a nested STEM ecosystem (e.g., micro-environment, meso-environment, exo-environment, macro-environment, and chrono-environment), what they attend to, why, how, and how their understandings shape their cognitive and embodied decisions. I point to how their identities (i.e., race, gender, etc.) shape their stress engagements, which in turn shapes their responses, identity development, and outcomes, connecting different components of this metacognitive, cognitive, and embodied process to different facets of the STEM learning environment (e.g., Corwin et al., 2020; Morton, 2021; Morton & Parsons, 2018).

In my presentations, I also point to how the same type of process (though not the same experience, factors, etc.) is taking place for faculty, administrators, professional staff, and families. In essence, in looking at the STEM ecosystem, we can see multiple figured worlds (e.g., Holland et al., 1998) transpiring simultaneously with points of interaction, collision, collaboration, and other responses taking place all under a structured system of norms, rules, expectations, policies, and practices that are rooted in and governed by (power-wise) specific beliefs, values, and concepts of morality. When critically bounding this ecosystem and naming the presence and power of structural racism and intersectional oppression through Critical Race Theory (Crenshaw et al., 1995), I talk about how white supremacist ideologies, coloniality, anti-Blackness, and other perspectives situate everything transpiring within the STEM ecosystem. In the most colloquial way possible (recognizing many critiques of the metaphor that I am about to evoke), this perspective looks at people engaging STEM from a meta-multiverse lens akin to the multi-verse concept presented in the Marvel Comics.

I share this perspective as way to re-emphasize the core argument presented in this edited volume. Again, that is the fact that everyone, particularly those who hold power, privilege, and status given their social identities and/or their social ranks (e.g., professions, role within family/community structures) must open their eyes to how the STEM ecosystem is currently situated, even the DEI space. People must not only see, but they must leverage their power, privilege, status, and position to disrupt, deconstruct, dismantle, and decolonize knowing, being, and doing in STEM. They must also invest in, embrace, and uplift critically imagined, pluralistic perspectives and possibilities that attempt to embolden or at the very least commit to doing no further harm to people historically and contemporarily excluded and marginalized.

The authors of this edited volume gave direct (and indirect) charges to funding agencies, editors, policymakers, and administrators. I am extending these charges to everyone else not listed. And I end with both a question and statement. The question, situated in this perspective of disrupting, deconstructing, dismantling, and decolonizing is the same question posed by Janet in 1986, asking on the behalf of those of us historically and contemporarily excluded and marginalized: ***"what have you done for US lately?"*** And no, not the U.S., but US as in the people who experience and consistently fight oppression. The statement, written and performed by singer, songwriter, producer Siergio in his recent song "Take You Out" (see www.siergiowashere.com to listen) is that "**I Don't Want To Hear No Excuses…".**

When reflecting over your answer to the question "what have you done for us lately" given the framing presented by the authors of the book, just know that we, the people who have been historically and contemporarily excluded and marginalized, "don't want to hear any excuses" regarding what you have not done or why your actions have not led to transformative change. Our experiences, trials and tribulations are well documented. Representation, alone, does not foster liberation. And the efforts of those attempting transformative, structural change is present, willing, and ready for more people and more sustained resources to advance this cause.

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