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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