Policy Issues in Science Education: The Importance of Science Teacher Education, Equity, and Social Justice

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As the number of students of color grows significantly in the nation's schools, policymakers, administrators, and teachers alike must work in tandem to ensure that all students receive equitable learning opportunities. As such, science teachers and science teacher educators face increasing pressure to bridge the gap between their pedagogical content knowledge and students' learning outcomes. In the chapter "Equity and Diversity in Science and Engineering Education," the National Academy of Science (2011) provides two reasons for the differences among specific groups of students in their educational performance and patterns of science learning. One reason provided by the Academy includes inequities across schools, districts, and communities, and differences. This also includes differences in opportunities related to curricular and instructional materials and assessment/evaluation. Additionally, the Academy lists elementary science preparation, literacy, and mathematics understandings as pressing challenges to students' performance in science. While the onus for low student performance is often placed on teacher effectiveness, educators and policymakers should also consider how curriculum and policy decisions impact student learning and student outcomes. In the case of science teacher education programs, an emphasis on multicultural course offerings might provide teachers with a better understanding of students. For example, courses that delve into students' cultural and social capital should be foundational in teacher preparation courses. In turn, this might encourage students to exhibit a better

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appreciation for the subject matter. We posit that teacher preparation programs should encourage teachers to understand and value student differences and respond to those differences in their teaching styles. To be clear, we do not advocate teaching from a deficit perspective; however, we suggest that teachers should value the diverse perspectives and knowledge that all students bring to classrooms (Milner, 2010). Furthermore, we suggest that policy initiatives that seek to increase performance for low-income rural and urban students consider a framework that speaks to the differences that students bring to classrooms. Thus, the purpose of this chapter is to review science teacher education policy in conjunction with standards to which teachers teach. Moreover, this chapter sets forth a new policy agenda to improve science teacher practices and science performance among low-income rural and urban students of color.

Teaching Strategies for Meeting the Needs of Today's Students for Tomorrow's Future

Before prospective teachers enter a teacher preservice program, they come to the program with their own epistemologies or ways of seeing the world. For some teachers, this lens does not include low-income rural and urban students of color excelling in STEM subjects (Bryan & Atwater, 2002). This deficit way of depicting students' interests in science trickles down to the way some teachers teach. Jones and Carter (2007) suggest that teachers' epistemological beliefs tend to be relatively stable and resistant to change. Thus, many teachers rarely depict low-income rural and urban students or students from traditionally underrepresented groups (i.e., African American, Latino/a) as future scientists. While this culture is endemic in many of today's science education classrooms, it is also reified in the larger school community. As such, teachers' contexts often influence their practices. Given that, then, how do science teacher education programs break the stereotypic cycle that some teachers bring to the science teacher education classroom? Social justice researchers propose that the major goal of research is to develop action agenda to address the lives of marginalized, oppressed groups (Atwater, 1996; Barton, Ermer, Burkett, & Osborne, 2003; Cochrane-Smith & Fries, 2011; Darling-Hammond, 2006; Rodriguez, 1998; Seiler & Elmesky, 2005). More specifically, social justice researchers propose the following: (a) include the history of science in the curricula to demonstrate that science is a human endeavor and aids students in understanding that social and political powers are tied to science; (b) teach the history of science so that students can understand the many contributions of other cultures to science; and (c) teach the history of science so that students can learn about their cultural heritage and provide them role models for the their future endeavors. As a result, a social justice approach to teaching science education might provide students with tools and concepts to better understand their role in producing science knowledge.

Loughran (2007) suggests that science teachers, along with science teacher educators, traditionally utilize transmission approaches to teaching. Subsequently, the transmission approach to teaching proposes that telling students will promote science learning as opposed to engaging students in their own learning (Tishman, Jay, & Perkins, 1993). Students learn science by *doing* science. Therefore, in order for teachers to engage learners, teachers should relate scientific concepts and processes to students' background and heritage. This, we believe, will help students to view science as a more attainable subject. This approach may also lead to better academic performance gains among low-income students and underrepresented students of color in science education (Julyan & Duckworth, 1996; Parsons, 2003).

O'loughlin (1992) maintains constructivist teaching is fallacious because of its inability to come to terms with the essential issues of culture, power, and discourse in the classroom. He argues that a sociocultural approach to teaching and learning takes seriously the notion that learning is situated in the following contexts: (a) students bring their own subjectivities and cultural perspectives to bear in constructing understanding; (b) issues of power exist in the classroom that need to be addressed; and (c) education into scientific ways of knowing requires students to understand modes of classroom discourse. If students understand classroom discourses, then they will be able to negotiate these modes effectively. This will allow students to master and critique scientific ways of knowing without sacrificing their own personally and culturally constructed ways of knowing.

A Review of Science Teacher Education Policy and Standards

Science teacher education policy implemented during the 1960s and 1970s emphasized teacher competency and science mastery learning (Yager, 2000). During the 1980s, science teachers were viewed as "knowers"; therefore, teachers' practical knowledge dominated science teacher education literature (Abell, 2007). Teachers' pedagogical content knowledge (PCK), along with science content knowledge, was of interest to science teacher educators. During that time, science teacher educators focused on the following areas: (a) teachers' knowledge of goals for and general approaches to science teaching; (b) teachers' knowledge about the science curricula, including national, state, and district standards and specific science curricula; (c) teachers' knowledge about assessment of students; (d) teachers' knowledge about science instructional strategies, including representations, activities, and methods; and (e) teachers' knowledge of student science understanding (Abell). Although these standards were intended for teachers to use with all students, they were not designed for low-income rural and urban students. In an effort to ensure that low-income rural and urban students were taught science from the same standards, Shulman (1986) developed teacher knowledge bases that included the following: (a) content knowledge; (b) general pedagogical knowledge, with special reference to the broad principles and strategies of classroom management and organization that appear to transcend subject matter; (c) curriculum knowledge with

particular grasp of the materials and programs that serve as "tools of the trade" for teachers; (d) pedagogical content knowledge (a special amalgam of content and pedagogy); (e) knowledge of learners and their characteristics; (f) knowledge of educational contexts, ranging from the workings of groups or classrooms, the governance and financing of school districts, and the character of communities and cultures; and (g) knowledge of educational ends, purposes, and values and their philosophical and historical grounds. These standards allowed teachers to reach inside the lived experiences of students, thus extending science education beyond "generic" learners. As a result, Shulman's model (1986) for understanding teacher knowledge became of great interest in science education.

During the 1990s *The National Science Education Standards* (1996) created standards related to science teaching, assessment in science education, science content, and science education programs. In the assessment standard, Standard D states, "Assessment practices must be fair" (p. 85). However, this standard focuses on bias and includes "Assessment tasks … must not assume the perspective or experience of a particular gender, racial, or ethnic group" (p. 85). This standard, which is developed on a color-blind ideology (Bonilla-Silva, 2006), poses problems for students of color and women in science interested in science education. In a traditional sense, assessment items are based upon a White dominant paradigm, and it is assumed that all races and genders of students should understand concepts through a White male epistemological lens (Linn & Harnish, 1981). This lens negates equity or social justice as it relates to the preparation of science teachers. As Milner and Williams (2008) note, "standardized" policies that do not take into account the multiple layers of needs and issues in particular contexts often result in inequities and inequalities that are difficult to control.

The turn of the twenty-first century brought with it reform of the 1965 *Elementary and Secondary Education Act*. This reform, known as the *No Child Left Behind Act* (NCLB) of 2001 called for all students to be proficient in all subjects by the year 2014. This federal education policy required disaggregated data of student subgroups. These data indicate that students from underrepresented groups (i.e., ELL, African American, and students with disabilities) lag behind their White counterparts in most subject areas, but particularly in mathematics and science. The exposure of such data reveal that one possible cause of the differences among student performance is the widened gulf between teacher subject matter knowledge to other forms of teacher knowledge, teacher beliefs and values, and classroom practice (Ferguson, 2003; Gess- Newsome, 1999; Norman, Ault, Bentz, & Meskimen, 2001; Parsons, 2005). It also suggests teacher classroom practices and students' cultural backgrounds are disconnected. As federal policymakers prepare to reauthorize and make legitimate changes to NCLB, science teacher educators must continue to ensure that required objectives and goals have a multicultural component as a means of meeting the needs of all students.

If science teachers envision science teaching as aligning with the national standards, then it is imperative that the standards include issues related to equity and social justice in the learning and teaching of science and the assessing and evaluating of students' science knowledge and skills. Currently, the nation's proposed

common core of standards does not include a standard that focuses specifically on equity and social justice. Instead, the common core includes a standard that aims to meet equity and social justice objectives. The standard, *Connections in Teaching Science*, provides learning objectives for students that include the following: (a) the examination of science applications in their personal lives and interests and in the examination of local issues and (b) relating knowledge of other disciplines, particularly mathematics and social sciences, to concepts of science in applications to their personal lives. While these objectives provide students with an opportunity to apply science knowledge to their daily-lived experiences, it does not allow teachers to highlight such experiences as a teaching focus. For instance, the knowledge objective for teachers includes understanding how students can identify and utilize science concepts in their daily lives. In order to improve science performance for low-income students of color in rural and urban schools, then teachers must be committed to being change agents in the profession.

Unlike the common core of standards, the National Board of Professional Standards of Teaching includes standards related to equity and social justice. For the adolescent and young adult (high school), the standards are as follows: (a) VI—Promoting Diversity, Equity, and Fairness-Accomplished Adolescence and Young Adulthood/Science teachers ensure that all students, including those from groups that have historically not been encouraged to enter the world of science and that experience ongoing barriers; (b) XII—Connecting with Families and the Community-Accomplished Adolescence and Young Adulthood/Science teachers proactively work with families and communities to serve the best interests of each student; and (c) XI—Family and Community Outreach-Accomplished/Science teachers proactively work with families and communities to serve the interests of students. While these standards exist, most schoolteachers do not adhere to the standards because many do not seek National Board Certification. Again, this suggests a disconnect between the world of policymakers and practitioners in terms of teaching students through an equitable framework.

The National Council for Accreditation of Teacher Education (NCATE) does not include standards that are specifically related to teachers and social justice. Instead, NCATE standards are based on a belief that caring, competent, and qualified teachers should teach every student. Given that, NCATE standards indirectly prepare teachers for a diverse community of students. Within NCATE, the National Science Teacher Association (2003) designed standards for science teacher education programs. These standards call for candidates to show how they take into account student differences in their planning and teaching. However, even within these standards, there are no standards specifically for science teacher educators.

Although other national organizations struggle with including standards that address equity and social justice, The Association for the Education of Teachers in Science (AETS) in 1997 clearly defined a framework for the knowledge, skills, experiences, attitudes, and habits of mind essential for highly qualified science teacher educators at the beginning of their professional careers. These standards were established to guide the development and revision of graduate-level programs that prepare science teacher educators, criteria for the qualifications of a

university-level science educator, and guidelines for the qualifications of individuals. Those who could be science teacher educators were higher education faculty members who have coursework in the science subject matter and/or science pedagogy, school-based mentor teachers, school personnel who conducted professional development activities, and other agency personnel who provided professional development to science teachers. The standards are intended for early career science teacher educators since AETS believed that a lifetime effort is required to develop into an excellent science teacher educator. Given that, the standards focused on (a) the knowledge of science; (b) the knowledge of science pedagogy; (c) the theoretical and practical background in curriculum development, instructional design, and assessment; (d) the knowledge of learning and cognition; (e) the knowledge and skills for research/scholarly activity; and (f) the knowledge, habits of mind, and skills necessary to work with prospective and practicing science teachers as they move through a developmental process. Even though these standards were developed 15 years ago (Lederman et al., 1997), it is still very surprising that it was not one standard related to science teacher educators' knowledge and skills to prepare science teachers to teach students of color in urban and rural settings. In addition, there was no mention of equity or social justice. It was not until 2004 after the Association for the Education of Science Teachers (AETS) changed its name to Association of Science Teacher Education (ASTE) that its *Position Statement for Science Teacher Preparation and Career-long Development* called for science teacher education programs to engage prospective teachers in substantive clinical experiences where they develop and implement lesson plans appropriate for students from diverse backgrounds, assess their success on student learning, and plan next steps to improve their teaching.

Recently, The Carnegie Corporation of New York, along with the Institute of Advanced Study, took a bold move by calling for the creation of a common set of K-12 standards in science. In order to accomplish this task, the Carnegie Corporation initiated a two-step process by first developing a framework and then developing a set of science standards for the twenty-first century. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core ideas* has been published (National Research Council, 2012) and is built upon the *Science for All Americans* and *Benchmarks for Science Literacy* (1993) and the *National Science Education Standards* (1996). As the presidents of National Academy of Sciences and National Academy of Engineering (National Research Council, 2012) assert, "The frameworks highlight the power of integrating understanding ideas of science with engagement in the practices of science and is designed to build students' proficiency and appreciation of science over multiple years of school" (p. x). There are several goals for the frameworks, but the most pertinent goals for this chapter include (a) "all students are careful consumers of scientific and technological information related to their everyday lives" (p. 1) and (b) "to guide the development of a new standards that in turn guide the revisions to science-related curriculum, instruction, assessment, and professional development for educators" (National Academy of Science, 2011, p. 2). Since US schools serve students from a variety of cultural

backgrounds, one would assume that this document would discuss cultural issues and equity in some detail. However, we find that there are basically two sections that address cultural issues and equity in this framework. The sections are summarized below:

- Most students can engage in and learn complex subject matter, such as science and engineering, when they connect to their personal interests and consequences.
- Many students lack essential material resources and instructional support for exemplary science instruction due to their socioeconomic class, race, ethnicity, gender, language, disability designation, or nationality.
- Many students are at risk for academic failure in elementary schools in certain geographic locations.
- If science is viewed as a culturally mediated way of thinking and knowing about natural phenomena, then students and teachers do not leave their cultural world views at the classroom door.
- Many traditional science classroom practices are ineffective with certain students whose family discourse practices differ from those found in schools.
- The ways that science learning is evaluated are problematic due to language issues, students' beliefs and attitudes toward certain kinds of tests, and test bias.

We, the authors of this chapter, find it problematic that in these sections that little to no research conducted by African American, Latino/a, or Native American science education researchers guides the framework. It is as the research findings of only European American education researchers seem to matter (Scheurich & Young, 1997).

With 13 recommendations for providing guidance to future standard developers, one focuses on diversity and equity—"In designing standards and performance expectations, issues related to diversity and equity need to be taken into account. In particular, performance expectations should provide students with multiple ways of demonstrating competence in science" (National Research Council, 2012, p. 307). The problem is that equity is an issue that should be infused in each of the standards since student learning is pivotal in this discussion of frameworks and science is a human endeavor. But the most problematic proclivity of this group is the terminology used to characterize people in such a way that their commitment to equity can be questioned. For instance, the term "African American" is hyphenated and the term "minority" is used. These writing practices go against the sixth edition of the *Publication Manual* of the American Psychological Association in its Reducing Bias section (2010). Thus, it makes us raise the question: How committed is the National Research Council to developing standards so that students from different racial, ethnic, language, ability, socioeconomic backgrounds will truly experience high-quality science learning and teaching?

As we think about answers to the above question, we suggest that the policy agenda thus far has not made an honest commitment to including low-income rural and urban students of color in science education curricula. That calls for a new policy agenda to be established that includes students from these groups.

Setting a New Science Teacher Education Policy Agenda

Based on the history of science teacher education policy and standards, and the current political pulse, science teacher educators and policymakers must work cooperatively to infuse multiculturalism with a focus on equity and social justice into the current science education policy agenda. This must be done by redefining the policy problem in science teacher education. We assert that one part of the problem includes low student performance among low-income rural and urban students and underrepresented students of color. Policymakers, on the other hand, do not understand the other part of the problem: lack of students' culture represented in standards and objectives. Before any policy problem can be a part of the agenda for change, then policymakers must see it as a problem, and "a problem is a problem only if something can be done about it" (Wildavsky, 1979, p. 4). Once policymakers realize the connection between student performance and teachers' understanding of student culture and background, then it will be accepted as part of the education reform agenda in science education. Additionally, "the more people affected by a problem, the more likely the item will receive priority on the legislative agenda, particularly if the effects are concentrated and serious, or extreme" (Cooper, Fusarelli, & Randall, 2004, p. 66). Once education policymakers connect science teacher education and student performance to the global economy and sustainability of this nation, then they will find it easier to make a case for including standards and objectives related to student culture.

After science teacher educators and policymakers manage to get students' culture on the education policy agenda for change in science education, then the policy implementation phase begins (Thompson, Wilder, & Atwater, 2001). Implementation is what happens when a policy is (or is not) carried out (Sabatier & Mazmanian, 1981), and it is in the implementation phase when most policy agenda items go awry. Oftentimes those who develop policy are loosely connected to those who implement policy. This, in turn, creates a divide that often results in poor implementation. In the case of science teacher education, it often results in mediocre classroom practice. Lackluster practice is not necessarily a characteristic of ineffective teachers, but it is often related to teachers not understanding what is being asked of them. This results from teachers not been asked to play a major role in the policy formulation phase. Thus, it is imperative that science teacher educators have a voice in setting the policy agenda as it relates to science teacher education and science education. Rarely, if ever, are teachers asked to partake in the policymaking process. However, they are expected to act as "street-level bureaucrats" and implement policies with fidelity. This, in many instances, creates a breakdown in the intended consequences of policy implementation.

Based on a review of teaching strategies and policies related to science teacher education, we propose an equity and social justice framework for science teacher education that includes the following elements: (a) equity in the development of science teacher education policy, (b) curriculum framework that encourages culturally relevant and culturally responsive teaching, and (c) equity in learning

opportunities for marginalized students. If science teacher educators have a larger voice in the development of policy that impacts students from various backgrounds, then policy will be more inclusive and more equitable. For example, science teacher educators from Alabama should have a seat at the table as well those from Massachusetts. In that way, the lived experiences and realities of students will be represented in the development of science teacher education policy.

In addition to more equitable development in science teacher education policy, we suggest that curriculum development should center around culturally relevant and culturally responsive teaching. This, we believe, must be bolstered by curriculum in science teacher education programs and district professional learning opportunities.

Once policies and curriculum are developed to be more inclusive (Atwater & Suriel, 2010), then we also suggest the equitable learning opportunities are afforded to students. This exists beyond the local level. It also includes more access and representation in internships and fellowships at nationally and internationally acclaimed think tanks, foundations, and universities.

As we have identified a science teacher educator policy and practice framework for equity and social justice, we reiterate the role of science teacher educators and science teachers as change agents in the process. Since most US students do not perform well on international science tests (Fleishman, Hopstock, Pelczar, & Shelley, 2010), then few students will become scientifically literate. This is the case even though inclusive science instruction, science learning as a cultural accomplishment, scientific discourse, students' prior interest and identity, students' cultural funds of knowledge, making diversity visible, and multiple modes of expression are advocated. Hence, science teacher educators are expected to prepare teachers to be at least competent in (a) inclusive science instruction, which includes using students' informal or native language and familiar modes of interactions, building on students' prior interests and science identities, and leveraging students cultural funds of knowledge, (b) understanding that science learning is a cultural accomplishment, and (c) valuing multiple modes of expression, especially in terms of assessment/evaluation. If science teacher educators prepare science teachers in this way, then we will see long-term gains in science performance.

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