

Infusing Social Justice into the Science Classroom:

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Building a Social Justice Movement in Science Education

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Abstract

Finding ways for all students to engage meaningfully with science and learn to use scientific knowledge and skills to identify and solve personal and community-based problems requires more than making changes to the curriculum students experience in schools. This article describes a methods course, part of a one-year masters level teacher preparation program, designed to prepare science teachers to make social justice a guiding principle in their work. The article argues for adopting a social justice lens as a focus for the preparation of science teachers and presents a framework for understanding what social justice means in the context of teaching and learning about science. The article includes an account of course readings and assignments, and examines teacher candidates' initial work for evidence of their developing views of teaching science with a social justice focus.

Introduction

Research suggests that many students, particularly girls and

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students from minority groups underrepresented in the sciences (URM), find science unattractive because the topics covered are perceived as uninteresting, unrelated to students' lives outside of school (Christidou, 2011), and disconnected from the knowledge of science that students bring into the classroom (Barton, et al., 2011). The forms of pedagogy currently in use in many science classrooms reflect views of scientific practice that are too distant from students' experiences and the problems or questions they face in their communities (Brickhouse, Lowery, & Schultz, 2000). In addition, these forms of pedagogy often ignore or reinforce a science culture that has actively excluded, oppressed, and even abused women and people of color. This article argues that successfully changing both science itself and science teaching to provide access for more people and create a more inclusive science culture, requires more than changing the curriculum of the science being taught; it requires "positioning the learner as a growing member of a community, with expanding roles and responsibilities" (Freire, 1970, cited in Barton, et al. 2011), and broadening the views of the communities and people who engage in science as citizens and as scientists (Eisenhart & Finkel, 1998). Changing science practice in this way hinges critically on the preparation of science teachers who bring a social justice lens to bear on their teaching and who can develop curriculum and facilitate classroom experiences that engage all students to help them see the relevance of science in their daily lives.

Social justice science teaching requires that pre-service science teachers come to see all students as capable of learning science, and that they also come to see the goals of science education as more than preparing a subset of their students to be scientists or engineers. This means transforming preservice teachers' view of the goals of science education from one that prioritizes the transmission of science content and skills, to one that emphasizes developing scientifically literate citizens who can identify and begin to solve science-related problems that are of importance to their families and local communities. This kind of science education demands that candidates make a range of fundamental changes in their thinking about science teaching, including: rethinking the content they teach; adopting more inclusive pedagogical strategies; reconsidering their beliefs about who belongs in science classes and who does not; adopting a critical approach that "equips students to 'talk back' to the world... [by posing] essential critical questions" (Rethinking Schools editors, 2004); and embracing an explicitly "multicultural, anti-racist, pro-justice" stance in the classroom (*Rethinking Schools* editors, 2004). Helping pre-service science teacher candidates develop and apply such a social justice lens in their classrooms is essential if we are to create science classrooms where all students are prepared for life as socially conscious and active citizens who can use science for personal and community purposes.

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In this article, I describe the creation and implementation of a methods course designed to prepare science teachers to make social justice a guiding principle in their work. I begin with a discussion of my reasons for adopting a social justice lens as a focus for the preparation of science teachers at this time and then describe a framework for understanding what social justice means in the context of teaching and learning about science. This includes a rationale for using this framework to understand and identify socially just science content, create a culture of critical inquiry, and apply learning to democratic citizenship. In addition, I include descriptions of assignments I use in the course and examine teacher candidates' initial work for evidence of their developing views of teaching science with a social justice focus.

Context

I teach in a mid-sized Master of Arts in Teaching (MAT) program where I am both the Program Director and the science content specialist. Our 13-month program aims to prepare middle and high school teachers in English, Math, Science, Social Studies, and Visual Art to make social justice a central tenet of their teaching. A focus on social justice is infused in all phases of the program, beginning in the first summer with courses in educational foundations, culturally responsive teaching, and adolescent development. It continues throughout the remainder of the program in all courses, including the content area methods courses. I teach the year-long science content area methods course to all candidates preparing to be science teachers (including biology, chemistry, integrated science, and physics teachers). The class meets twice weekly in the fall semester and once a week during the spring semester. In this class, my goal is to prepare science teachers who can: (1) clearly identify and describe the connections they see between science teaching and social justice; (2) plan units and lessons that explicitly include a social justice component; and (3) effectively implement their social justice and science teaching vision in the classroom.

Why Bring a Social Justice Lens to Science Teaching?

I have three reasons for focusing on social justice in the science classroom, particularly in 2018. First, attacks on science and scientific ways of knowing have been a part of science education in the United States at least since 1925 when Tennessee substitute teacher, John Scopes, was found guilty of violating the Butler Act which made it unlawful to teach evolution in a public school (for a detailed history of this trial, see Larson, 1997). Over the past decade, attacks on science knowledge and

attempts to legislate and restrict science teaching have again become a regular part of the U.S. landscape around a variety of issues that include the theory of evolution, human-caused climate change, and the safety of vaccinations. During the spring of 2017, for example, the Heartland Institute, a self-described “free market think tank” sent tens of thousands of science teachers a booklet titled, “Why Scientists Disagree about Global Warming,” a publication that makes the false claim “that scientists disagree about the environmental impacts of the combustion of fossil fuels on the global climate” (Heartland Institute, 2017). Not long after that, in the June 2017, both the *Washington Post* (Kaplan, 2017) and the *New York Times* (Harmon, 2017) featured articles about science teachers facing a new challenge in the classroom: parents and students who deny the evidence that supports the connection between human activity and climate change. In both cases, the teachers in these stories worked in states where citizens are deeply skeptical of scientific explanations that implicate human activity in climate change, and regularly face students and parents who loudly reject these explanations and resist their inclusion in the science curriculum.

For example, Harmon (2017) shared that a student responded to evidence of human-caused changes in climate with the claim that “scientists are wrong all the time” (para. 4). Another student in Kaplan (2017) explains, “most kids here honestly don’t really believe in climate change because their parents don’t” (para. 15). In Idaho, where one of the teachers works, “the state legislature urged the state board of education to rewrite the science curriculum to eliminate what one lawmaker called, ‘an over emphasis on human caused factors’ [of climate change]” (Kaplan, 2017). The Idaho debate continues in 2018, as legislators “watered down” sections of the new state education standards that refer to climate change, despite efforts by science educators to resist these changes (Albeck-Ripka, 2018).

These attempts to legislate science education are not isolated. A 2017 bill in the Iowa Legislature mandated that: “If a teacher provides instruction relating to evolution, the origins of life, global warming, or human cloning, the teacher shall include opposing points of view or beliefs relating to the instruction” (Iowa State Publication No. HF 480). The Alabama legislature (Alabama House Publication No. HJR 78) is more subtle in making science itself the object of skeptical inquiry and encouraging teachers include different views as a matter of “respect” rather than evidence. The text of the bill includes this guidance:

Teachers should endeavor to create an environment within public elementary and secondary schools that encourages students to explore scientific questions, develop critical thinking skills, analyze the scientific strengths and weaknesses of scientific explanations, and respond appropriately and respectfully to differences of opinion

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about scientific subjects required to be taught under the curriculum framework developed by the State Board of Education. (p. 2)

This language does not explicitly call out evolution or climate change but requires teachers to encourage debate about accepted scientific theories as a regular part of their teaching. Other states, including Louisiana, Tennessee, Mississippi, Indiana, South Dakota, Missouri, Florida, and Oklahoma have attempted to pass similar legislation. These efforts reflect an increasing tendency on the part of some of the most powerful people and organizations in our society (e.g. legislators and well-funded “think tanks”) to call scientific inquiry itself into question and attempt to replace scientific ways of knowing with what the conservative Discovery Institute describes as a “program designed to ‘reverse the stifling dominance of the materialist worldview and to replace it with a science consonant with Christian and theistic convictions’” (Haberman, 2017, para. 8). As Atul Gawande (2016) noted in his commencement address at the California Institute of Technology:

Even where the knowledge provided by science is overwhelming, people often resist it—sometimes outright deny it. Many people continue to believe, for instance, despite massive evidence to the contrary, that childhood vaccines cause autism (they do not); that people are safer owning a gun (they are not); that genetically modified crops are harmful (on balance, they have been beneficial); that climate change is not happening (it is). (para. 4)

My second reason for taking an explicitly social justice-focused approach to science teaching is that despite decades of effort to increase the participation of women and people from underrepresented minority groups (URM) in STEM majors and careers, and despite the increasing diversification of the US population as a whole, participation in STEM majors and careers remains stubbornly male and white (Landivar, 2013; National Science Foundation, 2015). Indeed, the situation appears to be worsening. According to a report published by the organization Change the Equation (February, 2015), while:

between 2001 and 2014, whites and Asians declined from 74 to 69 percent of the working population...their dominance in critical STEM occupations continues unabated...In fact, African Americans and Latinos are less likely to pursue careers in engineering, computer science, or advanced manufacturing than they were in 2001...[and] women remain as scarce as ever. (para. 8)

In addition, interest in science and math, although high among young children (Osborne, Simon, & Collins, 2003; Riegle-Crumb, Moore, & Ramos-Wada, 2010), falls off before those students even reach college (Maltese, Melki, & Wiebke, 2014).

While we need to actively recruit a more diverse group of people into STEM fields in order to fill STEM jobs in an increasingly diversified

society, we also need to increase the diversity of the people who participate in STEM careers for the benefit of science and society. A more diverse STEM workforce is needed to more creatively and effectively identify and propose solutions for the problems we face as a modern society. As Kenneth Gibbs states: “When we consider scientific research as group problem-solving, instead of the unveiling of individual brilliance, *diversity becomes key to excellence* [emphasis in original]” (Gibbs, 2014, para. 8). Medin and Lee (2012) also assert:

we cannot and do not shed our cultural practices at the door when we enter the domain of science, science education, or science learning” explaining that “validity in the sciences... involves choices about what problems to study, what populations to study and what procedures and measures should be used. In making these choices, diverse perspectives and values are important. (para. 2)

Scientists of different genders, ethnicities, and backgrounds identify different problems, devise different methods for studying them, involve different populations in their studies, and even interpret results differently. Increasing the diversity of perspectives brought to bear on the problems we face will inevitably lead to new and different ways of solving those problems. If we are to succeed in developing solutions to the kinds of complex problems we face and if we are to continue to identify new problems and new approaches to solving them, we need a diverse group of STEM professionals to carry out that work. In addition, if we are to create a culture in STEM careers that is open and welcoming to more people, including more diverse groups of people in those careers is an essential first step.

My third, and potentially most important, reason for bringing a social justice lens to science education is that it is essential that every citizen feel confident and willing to bring knowledge of science and math to bear when making personal and societal decisions. Full participation in a democratic society requires that all citizens understand the process of science and are able to use scientific concepts in making personal and social decisions. Whether or not they are pursuing careers in STEM fields, it is essential that we find ways to maintain people’s interest in science and their ability and willingness to use scientific information as a part of individual and collective decision making.

Despite over fifty years in which many countries, including the US, have declared that “science for all” is a central goal for science education, exhorting schools to “prepare all students to make sense of science in daily life” (Feinstein et al, 2013), it is not at all clear that there has been significant or measurable progress made toward this goal. Science curriculum still largely consists of units, lessons, and assessments focused on content that is largely removed from students’ everyday experiences, and many schools still clearly see the primary goal of science teaching

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as preparing students for the next level of science education, focusing most resources on students who see science as a career, not on students who could come to see science as a way to investigate and make decisions about science-related personal and social issues.

It should come as no surprise to anyone that teachers have been shown to play an important role in students' decisions about continuing to pursue science and math beyond high school. Women are negatively affected by educational experiences more than men, particularly when the women's teachers exclude them from science activities (Maltese, Melki, & Wiebke, 2014). Ineffective science teaching can also lead to a loss of confidence in students' abilities to understand and apply STEM concepts in everyday life. As noted earlier, science education researchers suggest that many young people find science uninteresting because the content is perceived as unrelated to their lives outside of school (Christidou, 2011) and disconnected from the knowledge of science that they bring into the classroom (Barton et al, 2011). Science teaching often reflects science content that is removed from students' experiences and the problems or questions they face in their communities (Brickhouse et al, 2000). A meta-analysis that reviewed US research in science education between 1998 and 2004 found that the instructional approaches that had the largest impact on student achievement was teachers using "enhanced context strategies" in which they "relate learning to students' previous experiences or knowledge or engage students' interest through relating learning to the students'/ school's environment or setting" (Schroeder et al, 2007). Effective science teachers help students see connections between science content and their lives and interests outside of school.

Some science teachers may also see their students as capable of learning science or not, depending on students' engagement with science content and/or on their ethnicity or gender. It has long been known that teachers' attitudes about who can succeed in school and who cannot can be communicated both explicitly and subtly to students, further distancing some students from the content that is being taught (Rosenthal & Jacobsen, 1968). Successfully addressing these challenges requires "positioning the learner as a growing member of a community, with expanding roles and responsibilities (Freire, 1970)" (cited in Barton et al. 2011, p. 11), and broadening the views of the communities and people who engage in science as citizens and as scientists (Eisenhart & Finkel, 1998).

One key aspect of a social justice-focused science education, then, is one that has as a central goal the preparation of citizens who see science and scientific ways of knowing as tools for identifying and addressing questions of importance to their local communities. Preparing science teachers who consider social justice as a central tenet of their teaching,

who seek to help their students see connections between school science content and issues that they identify in their neighborhoods and communities, is one way to help students come to see science knowledge and scientific ways of thinking as useful tools they can use to solve personal and community problems.

It is worth noting here the importance of explicitly considering the role of culture and identity in this context. In order to help students, learn how to use science to identify and solve problems of interest to them, teachers must understand both their students' diverse identities and how to explicitly connect science content and practices to the world in which those students live. This culturally relevant vision of effective teaching is not new. As Gloria Ladson-Billings (1995) describes in her essay, "Toward a Theory of Culturally Responsive Pedagogy," the terms "culturally appropriate," "culturally responsive," and "culturally compatible" have been used since the 1980s to describe instructional practices of teachers who incorporated aspects of students' cultural backgrounds into their instruction with Native Hawaiian, linguistically diverse, and Native American students. Further, Ladson-Billings focuses specifically on the role of culturally responsive practices in effective science teaching in her "Foreword" to the science methods textbook, *Teaching Science to Every Child* (Settlage & Southerland, 2007). After describing some of the experiences she encountered as an African-American girl growing up in a working-class urban community in the 1950s and 1960s, Ladson-Billings (2007) turns her attention to the ways that culturally relevant pedagogy can be a useful framework for helping to maintain students' interest and engagement with STEM topics and classes. She explains how the successful teachers she studied chose science content that is connected to students' interests and concerns, meaningfully integrate students' culture into the curriculum, and elevate students' socio-political consciousness by investigating real issues in local contexts. Teaching them "a science that explains the epidemic of diabetes or AIDS in their community...that challenges social constructions like race... [and teaches them] that people can mobilize to fight social injustice AND intellectually empower people." (Ladson-Billings, 2007, p. xviii).

Tan and Barton (2012) have explored these ideas more explicitly in the fields of math and science education, arguing for the development of an "empowering math and science education...built on three main ideas: transformation of discourses and practices, transformation of identities, and transformation of the spaces for learning/doing science" (p. 40). Their view of what they call "critical science literacy" focuses on engaging students with both science as it is and science as it could be, encouraging students to question accepted science knowledge and practices, broaden their view of who can and should participate in

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science, and learn to “participate in a democratic society in fair, just, and transformative ways” (p. 42).

This view of science education is far from the static, textbook-driven curriculum that many students experience. It is a view that takes seriously the cultures, experiences, interests, and concerns of students, and provides them with the tools they need to use science now (instead of in some indefinite future) to solve real problems of interest to them and their communities. It is a view that has the potential to engage all students in a science that is relevant to them, to empower them to use scientific knowledge and skills to solve personal and social problems, and to use their developing understanding of science as way to mobilize with their peers and communities to fight social injustices. It this vision of a social justice science education that I believe science teachers need to learn.

How to Help Science Teacher Candidates Re-Conceptualize Science Teaching

How can we help science teacher candidates (TCs) begin to re-conceptualize science teaching from a more traditional view, driven largely by textbooks, national standards, and a focus on content that is largely disconnected from students’ lives, to one that is meaningful, culturally relevant, and socio-politically situated? I propose three ways to help teacher candidates do this.

First, from the start of their preparation program, I encourage my TCs to reconsider the goals of science education. Rather than seeing the goal of science education as the preparation of future scientists, doctors, or engineers, I encourage the view that science education has as its central purpose developing citizens who can use science to answer their own questions and make informed decisions about meaningful personal and social issues. While encouraging more young people to pursue careers in STEM fields is a worthy goal for science education, taking that as the primary goal has neither helped produce a more scientifically capable or interested citizenry, nor a more diverse cadre of scientists and engineers (Barton et al, 2011; Tan & Barton, 2012). Instead, as noted earlier, STEM fields remain persistently male and White, with many women and people of color losing interest in science altogether (not to mention choosing not to pursue STEM careers), and with many students from all socioeconomic classes, races, and genders coming to see science as something that is not relevant to their lives. This leads to young people not only foregoing opportunities to pursue STEM careers, but also missing opportunities to build the knowledge and skills needed to critically assess scientific arguments and use scientific knowledge as citizens. These trends continue, despite the increasing

need for all people to understand and apply science concepts in personal decision-making as well as in policy-making at the local and national level. By refocusing science teacher education on helping all students learn to apply science content and skills to solving problems they identify as important to themselves and their communities, we can enable more students to see that science can be a powerful way to create a more just and equitable society and help them make their voices heard on topics of local and national importance.

Helping TCs take up a social justice lens in their teaching is not easy, particularly because there are powerful forces at work against this move, including the kinds of external constraints discussed earlier in legislative efforts to resist it. Most TCs are products of a traditional science education, both in K-12 schools and their undergraduate education. Most of them attended middle and high schools where tracking, leveling, or ability grouping was the norm, and where students who planned to pursue careers in STEM fields were given the best teachers and the most resources. The taken-for-granted assumptions about who does science and how it should be taught have been a part of their experiences throughout their education and adopting a different view about who can and should participate in science is not something that happens overnight.

In addition, because of the ways they have been taught, it is often difficult for TCs to imagine teaching in ways that put students' interests and questions at the center of the science curriculum. TCs have been successful in a system where science is typically taught through textbook reading assignments, lectures, and demonstrations (with periodic "cookbook" laboratory experiences). They have been rewarded for learning decontextualized science content through memorization, typically measured on multiple choice (or at best, short answer) tests. Most of them have done well in these settings and have few examples of student-centered learning to draw from when asked to plan alternative kinds of teaching.

My own experience bears this out—I grew up in a large, Midwestern, U.S. city, the daughter of parents who worked in higher education, and attended well-funded public schools where I was a successful student. It was not until I enrolled in a science education Ph.D. program, after a number of years as a middle and high school science teacher, that I began to question my assumptions about what a good science education looked like, and who benefited and who did not from the teaching practices in place in my and others' classrooms. It was at that point that I also began to explore my identity as a straight, white, cisgender, woman and its connection to my role as a teacher, and to revise my views about the goals of science education.

In order to help TCs begin to explore an alternative view of the goals

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of science education, I use three connected strategies: reflective writing, guided classroom observation, and critical reading. First, I ask candidates to reflect in writing on their own experiences learning and doing science. Some of the questions I ask them to think about include: What were the experiences they had, in school and out, that led to their interest in science and eventually to their desire to become a science teacher? Who were the adults (teachers, parents or guardians, others) and peers who encouraged (or in some cases, discouraged) them from their interest? What was their science education like and what do they remember as the most and least effective teaching strategies they experienced? What aspects of science learning did they find challenging and how did they respond to those challenges? What excites them about science now and how has that changed over time? These questions are designed to help them activate memories about their own science education as they begin to spend time in a science classroom at their student teaching placement. At their placement, I ask TCs to take note of how their mentor teacher gets to know their students, how they identify the content to be taught, how they plan for teaching, how they assess learning, and what kinds of activities and experiences are common in the classroom. During this time, I also require TCs to write a brief essay in which they outline their own views about the goals of a good science education.

Contrasting their experiences as learners with the practices in place in their student teaching practicum (where their mentors frequently struggle to implement more inclusive pedagogies themselves) sets the stage for critical readings and in-class discussions about alternative views of science teaching and learning, as well as examples of social justice-related science articles from current newspapers and other sources. Among others, for example, we read the introduction to *Rethinking Our Classrooms, Volume 1*, 2nd edition (2007) which opens with this statement:

Rethinking Our Classrooms begins from the premise that schools and classrooms should be laboratories for a more just society than the one we now live in. Unfortunately, too many schools are training grounds for boredom, alienation, and pessimism. Too many schools fail to confront the racial, class, and gender inequities woven into our social fabric. Teachers are often simultaneously perpetrators and victims, with little control over planning time, class size, or broader school policies—and much less over the unemployment, hopelessness, and other “savage inequalities” that help shape our children’s lives. (p. 4)

We read the Gloria Ladson-Billings (2007) essay about culturally relevant science teaching and look at data about opportunity gaps revealed by differences in test results by ethnicity and gender. We also read an essay titled “I Teach Science, Can I Be a Multicultural Educator?” (National Association for Multicultural Education, n.d.). We read chapters in

one of the required course textbooks (Tomlinson & McTighe, 2006) about how to differentiate instruction so that all learners have access to learning and pair that with another focused observation on how differentiation is implemented in mentors' classrooms. A short essay titled, "Challenging Cultural Stereotypes of Academic Ability" (Ong, 2008), asks TCs to consider their assumptions about who is interested in and capable of learning science. We also read and discuss a number of essays describing how science teachers develop curriculum units that connect classroom content with social justice themes, including: "Lead Poisoning: Bringing social justice to chemistry" (Zaccor, 2016); "Social and Environmental Justice in the Chemistry Classroom" (Lasker, et al., 2017); and multiple selections from the another required textbook, which is reviewed in this special issue, *A People's Curriculum for the Earth* (Bigelow & Swinehart, 2014). Candidates are challenged to bring in weekly "science in the news" articles with a social justice focus and to explain how they might integrate this content into their teaching, now or in the future. Examples shared in class during the fall 2017 semester included: "People of Color Are Living with More Polluted Air than Whites Are" (O'Neill, 2017); "New Gene Variants Reveal the Evolution of Human Skin Color" (Gibbons, 2017); "Estimated 80,000 Gallons of Sewage Flows into Columbia River" (Ryan, 2017); and "New Maps Show Big Divide Between the World's Overweight and Underweight Children" (Cha, 2017). As they read and discuss these varied materials, they continue to engage in focused classroom observations, getting to know more about who their students are and what they are interested in learning. They also look for ways to contrast what they see happening in their placements with their developing ideas about what could, and should, be happening. As they plan their first complete unit at the end of the fall semester they are asked how they plan to connect the content of the unit with a social justice theme. They then write a final essay describing their developing beliefs about science teaching and social justice.

This cycle of written reflection, focused observation, and critical reading is designed to help candidates consider and reconsider their developing ideas about what it means to implement social justice-focused science teaching in their own classrooms at the same time that they are beginning to develop and carry out instruction for the first time.

In addition to reflection, observation, and critical reading, I also provide candidates with two approaches to experiment with as they explore how to incorporate a social justice focus in their teaching. The first is modified from Tomlinson's framework for differentiating instruction (Tomlinson, 2017). Tomlinson's differentiation framework identifies three elements of the curriculum that can be differentiated: content, process, and products. Like the original differentiation framework, the social

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justice framework we use provides three “entry points” for including social justice in K-12 curriculum units and assignments: focusing a teacher’s attention on content (how science content is connected to broader social justice issues); process (pedagogical strategies that are culturally relevant and provide access and support for all learners); and assessment (demonstrations of learning that are authentically connected to students’ questions and concerns) (see Figure 1).

Candidates were introduced to this framework in mid-October, after reading some of the science and social justice curriculum examples. As a class, they worked in small groups to add examples in each column. Examples were saved in a shared document for future reference. Some of the candidates’ ideas for social justice *content* included: teaching about

Figure 1
Social Justice Planning Framework

A Framework for Integrating Social Justice into Science Teaching

CONTENT	PROCESS	PRODUCT
<i>Science content is connected to broader social justice issues</i>	<i>Pedagogical strategies are culturally relevant and provide access and support for all learners</i>	<i>Demonstrations of learning are authentically connected to students’ questions and concerns</i>
Science content helps students answer questions about local, regional, national, or global issues of concern to themselves, their families, and communities	All students are respected for the knowledge and experience they bring to the classroom	Students demonstrate their understanding by taking action to apply what they learn
Science content helps students pursue interests connected to their cultures and communities	Instruction is differentiated so that all students have access to the content, have a meaningful role in the classroom, and can take part in learning and sharing what is learned	Student work has a real purpose, and an audience who is engaged with, or able to take action on, the issue being studied
Science content is important—students can readily understand why they are learning it	All students are held to high expectations and given the support they need to be successful	

race as part of a unit on genetics; exploring questions about funding of scientific research; and teaching about climate change with explicit attention to who is responsible and who suffers the effects most powerfully. *Process* suggestions included: interviewing community members as a way to learn about local concerns and access local knowledge; showing multiple ways to approach problem-solving; and including more student choice as a regular part of instruction. Suggestions for *assessments* included: developing an activist campaign about an issue; developing PSAs, brochures or posters to teach others about what students learned; and creating a map documenting community assets and needs related to the content of a unit of study.

The second approach I ask TCs to explore borrows from critical theory and encourages them to frame each lesson they teach with guiding questions designed to help students explore the ways that science is a part of existing regimes of privilege and control. The three questions I encourage them to explore with their students are:

- Who benefits from this knowledge and/or its application in society? Who does not?
- Who participated in the development of these ideas? Who got credit?
- Who has access to this knowledge? Who does not?

While these questions may seem less disruptive than the modifications supported by the previous strategy because using them doesn't initially require rethinking content or instructional or assessment practices already in place (although their use can lead to those kinds of changes), they serve an important role in helping students to see science as something that can be interrogated and as a human endeavor that has been socially constructed by people with power. Teachers, even new teachers, can use questions like these to provide young people with the language to explore their own roles as users of scientific knowledge; to consider what it might mean to use science for personal purposes, and even to step into the shoes of scientists and begin to participate in the development of new scientific questions and the construction of new scientific knowledge.

Initial Impact and Challenges

To begin to understand the impact of this approach to helping TCs cultivate the skills and mindset needed to take an actively social justice approach to their teaching, I have begun to track the development of their ideas over the course of the first semester of a two-semester science methods course. As a result of a consistent focus on social justice and science teaching and the introduction of explicit strategies to support

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their thinking about their roles as social justice science teachers, the following outcomes can be seen emerging in TCs' work:

1. Candidates are motivated to include social justice as a part of their teaching.
2. Candidates' understanding of what it means to have a social justice stance as a science teacher has become more nuanced over the course of the semester.
3. Candidates can identify specific ways to connect their early unit plans to a social justice issue.

Candidates' motivation to include social justice as a part of their teaching can be seen in their ongoing persistence in asking questions about how to infuse social justice more effectively and consistently in their teaching. In addition, they work hard to learn more about their students and their communities. They look for ways to connect required content to student interests and to identify and use relevant, local, "science in the news" stories as a part of their teaching.

Candidates' understanding of what it means to be a social justice educator changes from the somewhat generic notion that "science is for all" to the more fully articulated idea that teaching science for social justice "provides opportunities to question, challenge, and reconstruct knowledge" (student, personal communication, 2017). They transition from worrying that parents will "lash out" at the inclusion of social justice content to the idea that social justice "involves being able to recognize inequities...and striving to not only recognize that specific groups of people suffer from inequity and injustice in their social and academic endeavors, but also what can be done to stop this cycle" (student, personal communication, 2017). They have progressed from describing social justice teaching as "engaging all kids with the material," to wanting to "foster an environment that promotes social justice through culturally responsive teaching practices" (student, personal communication, 2017).

TCs were all successful in fulfilling the requirement that their end of semester unit plan include an explicit connection to social justice content. Plans included: using the story of Henrietta Lacks to introduce a unit about genetics; exploring who is negatively affected by and who might benefit from global climate change; and investigating challenges associated with nuclear waste storage and disposal at a former nuclear weapons depot in a unit introducing students to atomic theory in chemistry. As a part of a unit on scientific inquiry, another candidate invented a local oil spill and recorded a video in which the school's principal asked students to develop and test effective ways to clean it up. Upon reflection, the candidate realized that there had been a real oil spill in a nearby community that could have served as a more authentic problem for her students to address. Another TC made sure to be conscious of her use of gender pronouns when talking about scientists and creating practice

problems, and intentionally highlighted the work of scientists from underrepresented groups. Another TC framed his unit with the following essential questions: Does the potential for space colonization reduce our efforts to preserve the earth? Is it the best use of our understanding of physics or are there other potential applications that we would be better suited pursuing?

Despite these promising early signs, a number of questions linger. First, it will be interesting to see the extent to which candidates' plans for including social justice content come to fruition as they begin to teach the units they have planned. As they move into the second semester of their teaching placement and take on more planning and teaching responsibilities, what factors influence the degree to which they continue to include social justice as a part of their planning? Even with the ongoing support and expectations that are a part of their science methods course, will the demands of a high stakes, state-mandated assessment (EdTPA) required for licensure distract them? Will the beliefs of their cooperating teacher/mentor about the importance of social justice and science teaching lead to more, or less, of a social justice focus? Will the candidates' own confidence in their planning and instructional skills lead to a more traditional approach to teaching and assessment? Will the specific content and grade level a candidate is teaching matter?

Second, and perhaps more important, is the question of the degree to which social justice becomes a regular part of these candidates' teaching practice after graduation. If we are to better understand the kind of preparation that supports TCs in developing into practicing social justice science educators, we also need to understand how their views of what counts as social justice teaching develop and change, and what approaches and tools they will need to support their work.

Transforming science teaching into a practice that engages all students in meaningful work with science that is connected to their lives beyond school is essential if we are to develop a scientifically literate citizenry comprised of people who are able and willing to use science to solve personally and socially meaningful problems. It is also needed if we are to succeed in populating STEM professions with a diverse cadre of people who more closely resemble the increasingly diverse makeup of the US population. Preparing science teachers who bring a social justice lens to their teaching is a powerful way to transform the science classroom from a place where only some students' cultures, interests, and ways of knowing are valued to a place where all students can actively participate in learning meaningful science that they can use to identify and solve problems of interest to them and central to the ongoing health of their communities. This is essential work for science teachers and the faculty and programs that prepare them to undertake.

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