Democratic Science Teaching

Building the Expertise to Empower Low-Income Minority Youth in Science

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Democratic science pedagogy has the potential to shape learning outcomes and science engagement by taking on directly issues of pedagogy, learning, and social justice. In this text we provide a framework for democratic science teaching in order to interrogate the purposes and goals of science education in classrooms globally, as well as to call attention to ways of being in the classroom that position teachers and students as important and powerful participants in their own learning and as change-agents of a larger global society. We develop three core conceptual tools for democratic science teaching, that together frame ways of thinking and being in classrooms that work towards a more just world: Voice, Authority, and Critical Science Literacy. Each conceptual tool is developed in the introductory chapters then taken up in different pedagogical and analytic ways in the chapters that span the text. The chapters present researcher, teacher, and student centered lenses for investigating democratic science education and reflect elementary through high school education, both in school and out of school, in the US and globally.
Democratic Science Teaching
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Scope
Research dialogs consists of books written for undergraduate and graduate students of science education, teachers, parents, policy makers, and the public at large. Research dialogs bridge theory, research, and the practice of science education. Books in the series focus on what we know about key topics in science education – including, teaching, connecting the learning of science to the culture of students, emotions and the learning of science, labs, field trips, involving parents, science and everyday life, scientific literacy, including the latest technologies to facilitate science learning, expanding the roles of students, after school programs, museums and science, doing dissections, etc.
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1. INTRODUCTION

JHUMKI'S JOURNAL ENTRY

Each day I would walk into my class at a public school in a Caribbean neighborhood in Brooklyn, I would believe that my students could and would become leading scientists of their generation and smart, articulate citizens able to shape the directions in which science led their world; young people who would use science to make change in the world.

And yet, time and again, I noted reality. Amidst a discussion of radioactivity, a knock-down fight broke out in my classroom between two intelligent, confident girls. A previously-incarcerated student who had spent hours after-school powering motors with solar panels was arrested for assault, moments before he was to proudly present his findings at the annual science fair. This recidivism occurred despite hours of individualized support from his teachers and father. He spent time in prison rather than preparing for his dream career in mechanical engineering. A medicine and engineering course I taught evolved into a time for “literacy-building,” undermined by a national emphasis on reading and math. A student deeply engaged with robotics had to “choose” between a science course and his special education services.

Meanwhile, engagement and excellence in my class were episodic. Every student boldly presented “original” work at the annual science fair and developed series and parallel circuits for powering household objects. But I’m quite sure that many students could not imagine how uncertainties about dark energy were relevant to their lives. Homework was likely often not completed because it did not have ties to the substance of students’ lives. As a teacher, I probably often assumed that what mattered to me mattered to all my students, that the joys and rewards of learning science were obvious, rather than situated in paradigms that excluded the backgrounds, aspirations and Discourse of many of my students.

These realities are not all realities. My students in Brooklyn cared about academic success. Ask almost any student, and she will tell you that she wants to improve her grades, be on honor roll, pursue a successful career. Ask most parents, and they will want these same things for their children. It seems the issues are more of resources and paradigms. The girls at the elite private school where I taught for two years often came from extremely wealthy families with a history of social and financial success and high-quality private elementary- and middle-school educations. They attended a resource-rich school offering the most challenging classes and
were told time and again by peers, teachers, families and the world that they had achieved plenty and could be anything they dreamed to be.

Where in their academic life, particularly in science, were the life histories of my students in Brooklyn valued? Were any connections built between how science is traditionally taught and the farm on which one of my students grew up? Clearly not – she said this had nothing to do with science. Did one young man’s delight in building toy boats as a child emerge through opportunities in his science classes? Did the young man engrossed with solar panels demonstrate his leadership skill in his science class? Did the 8th grader who tapped his pencil and squirmed endlessly in science class ever get time and space to exhibit his aptitude for building? And were these students told over and over, in what was formally said and offered to them, that they had the potential to learn science and be young scientists? Or instead, were they simply told to either adapt to the way science was taught or give up on their love of inquiry and knowledge?

RE/FRAMING URBAN SCIENCE EDUCATION IN A DEMOCRATIC SOCIETY

The seminal report, A Nation at Risk (1983) (ANAR), laid out the scenario that public schools would face in the coming decades, if significant changes were not made to the public education systems in place. Many of our schools located in growing urban centers were in crisis. Operating in deteriorating buildings, staffed by under prepared and unlicensed teachers, working in under resourced classrooms, not to mention the trend to staff inner city schools, that traditionally serve the academically neediest students, with the newest least prepared teachers. More egregious was the dysfunction in urban schools, the resulting student failure, and the reproduction of a ‘culture of failure’ within schools and communities. ANAR was published almost twenty years ago. Since that time many studies, narratives, and reports have commented on the factors that most impact upon urban school success and urban student achievement. Additionally, there is no shortage of information on what is ‘wrong’ in urban centers, including their schools.

Almost 20% of the nation’s students are living in poverty, with numbers increasing under the recession that begun in 2008. But in large urban centers, like New York City, Atlanta, Houston and Los Angeles, that number more than doubles to 35–45% (Institute for Research on Poverty, 2010). Further, nearly 40% of urban students are attending high poverty schools. Students living in poverty are more likely to attend schools with outdated texts, are offered fewer opportunities to participate in summer or enrichment programs, have less access to certified teachers in math and science, and consequently face higher degrees of academic failure, and also have higher high school drop out rates than their more affluent or suburban counterparts (Oakes, 2005).

Low performing schools in urban centers are characterized by low teacher morale, high rates of teacher turnover and more teachers teaching without or out of their license areas (Ingersoll, 2001; Ingersoll & Perda, 2010). In New York City, recent numbers indicate that they may have as little as one in two chance of having a certified math or science teacher (Chanc. Harold Levy, Mach 2004).
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In the wake of No Child Left Behind (NCLB) many poor, inner city schools/districts/systems find themselves in the midst of reform to ensure both improved educational outcomes and continued monetary support from the federal, state and city government. Most of these efforts are forced to conflate educational achievement with standardized test scores, even though many researchers point to the dangers of such unions. In addition to lagging behind in achievement, poor urban students are often not presented with the same opportunities to learn science. They are more likely to have unprepared teachers and have fewer chances to enroll in the advanced courses that are on the college bound trajectory (Ingersoll & Perda, 2010). Other studies indicate that poor students are more frequently tracked into low level science courses in which “good student behaviors” and rote memorization are valued more than the acquisition of dynamic science content, skill and process knowledge (Oakes, 1990).

Still, it would be remiss to suggest that lack of resources is the sole or primary barrier to creating and sustaining successful urban schools. The issue is far more complex and there are a myriad of contributing factors as well as societal forces strengthening the tensions that bound urban education.

For the past two hundred years public education has sought to provide basic skills and instruction in citizenry, morality and the 3 R’s. In 1830, the workingman’s committee of Philadelphia described the aspiration of the Common School this way, “Our main objective is to secure the benefits of education for those who would otherwise be destitute and to place them mentally on a level with the most favored in the world’s gifts” (Tyack, 1967). Essentially, it was believed that the greatest challenge was providing the children of all parents the opportunities to study together. Academic achievement was largely seen as a testament to the will and perseverance of the individual. Over the next hundred years these attitudes would persist and grow more deeply rooted in our culture. Students that failed were thought to be of a lesser moral character or to not have the mental capacity for success. In 1920, the superintendent of schools in Newark, New Jersey argued, “All children are not born with the same endowments and possibilities: they cannot be made equal in gifts or development or efficiency…the educational system must therefore be adjusted to meet this condition” (Deschenes, et.al, 2000).

Rarely, if at all, was instruction, its content or design, considered as a source of student failure. Even more absurd was the notion that the context or construct of schooling was to blame. In fact as the nation became more urban and more students enter the schools, rather than developing a variety of approaches to schooling, what developed was a litany of terminology used to label and separate out those students for whom the system fails. In the early 1800’s, these names read “dunce, wrong-doer, sluggish, stupid, incorrigible, and idle”, to name a few (Deschenes, et.al, 2000). By the beginning of the 1900’s, the list of names had expanded and shifted to include “sub-z group, mental deviates, laggards, average, occupational student, backward, and inferior” (Deschenes, et al., 2000). But, even as we look back at he first century of public schooling, our vision is often romanticized.

We envision the one room schoolhouse as some nostalgic harkening to another time and place rather than examining the harsh realities that it represented for the
less affluent family. Students typically only went to school for several months of the year—between planting and harvesting seasons and schools were crowded and under resourced. And although the non-graded culture of the environment allowed students to progress at a pace more in line with individual learning styles, it did little to address the numbers of students who became stagnant in their academic progress or failed to complete school at all (Deschenes, et al., 2000).

By the early twentieth century, members of the progressive education movement sought to challenge some of the political assumptions undergirding the notions of education as a means to equality. They were not prepared to disrupt the notion of the “age-graded” school that in its division of tasks mirrored the ever-growing factory culture that the US was becoming world renown for. But educators were beginning to question the efficiency of educating everyone the same way at the same time around the same subject matter. It was in this era that tracking became a formal part of public education and that we began to use the developing field of cognitive understanding to determine who would study what, and ultimately begin to orchestrate who will have the opportunity to become what (Deschenes, et al., 2000). Put nicely, we began to use aspects of cognition and assessment to remove those students who might slow or retard the progress of the normal student. From a purely efficacy-oriented perspective, this use of our evaluative tools was a smart one. But considering the desire to view school as a tool toward promoting equality among the American public, it must be called into question. What do we mean by equal? And who do we consider to be the citizenry? The waters are further muddied when we take into account the levels of achievement in certain subject areas compared to others, as well as the commodity-like values of certain discipline-based knowledge in the constantly morphing global economy.

When contemplating the purposes of public schooling in the postmodern era we can still place at its core, its role in the assimilation of new cultural groups and students into American culture. Society is told that the education provided can also be a tool to level the playing field and to prepare children of color and recent immigrants for greater opportunities in their future. However, as we review school and school system report cards nationwide, we see that the schools, especially those that serve the traditionally marginalized located in poor urban centers continue to fall short.

Competition, meritocracy and individual accomplishment drive success in American public schools and frame the “democratic” way of life for American school children. For those students living in and/or attending schools in poverty, most of whom are children of color, these values are often in direct opposition to the cultural norms and capital that is most appreciated within their own communities. If we consider, as Coburn suggests, “that a persons’ worldview is not just a philosophical by product of their cultural origins, but rather the very skeletal structure on which we hang our flesh of customary behavior”, then we must pose the question, “When a child’s’ worldview is left unvalued and expressionless in an educational setting, what should we expect in terms of engagement, investment and learning from that child?” Boykin insists that some of the cultural inconsistencies between students and schools and teachers may be to blame for student failure and lack of
motivation (Lynch, 2000). We extend this argument to include the culture of science as it is taught in schools, from a primarily positivist perspective that suggests its empirical, objective and linear attributes are most salient. We are forced to examine the questions, “What are the goals and purposes of public schools?” “What role does the teaching and learning of science play in attaining those goals?” and finally, “Are schools in poor urban areas designed, organized and allowed to function toward meeting those goals”?

Since the early 1900’s educators have continually sought to reform science education. Yet, no matter how or whom, the intent of the reformers has been to create more effective science instruction that leads to more scientifically literate citizens. Put simply, regardless of the students ability to engage or not and experience success or not, we, the members of the educational community continue to allow merely a superficial analysis of our failures in science education and we continue to blame and punish children for them. Our failures, are due in no small part to the curriculum and pedagogies employed in current public school science classrooms.

BUILDING A MORE EMPOWERING SCIENCE EDUCATION THROUGH DEMOCRATIC IDEALS

As the last section suggests, the great democratic legacy of American education has been to create (or at the very least maintain) a sub-class of citizens who are barely learning basic literacy and mathematics skills and are completely marginalized from opportunities to engage in critical, analytic thinking. Schools have regimented their learning such that they have no voice in what they learn, no space to shape the space, topics and process of their education.

And yet, schooling has oft been written about a place where students learn to engage and experience the ideals of democracy (Dewey, 1916; Giroux, 1989; Goodman, 1992). How have the ideals of democracy given way to sub inequality? How might youth come to experience schools in democratic ways when the history of urban science education in American frames youth as in need of fixing, and schools as ways to standardize experience?

Democracy is a challenging word to use in our postmodern world. In contemporary discourse, democracy has come to mean the right to free speech, to vote, a method of decision-making, a political culture, a form of government, an historical perspective, to name only a few referents. Global events, including war, increased deforestation, the collapse of the global economy, has helped to further redefined democracy as a political ideology.

Democratic education has been grounded not in a political process or ideology but in a way of seeking a common good through schooling. The work on democratic classrooms arises from a political literature (Lane & Errson, 2003) and includes a commitment to social justice (Satz, 2007; Rawls, 1971). In the US, the democratic classrooms and schools movement emerged in the late 1980s. Democratic classrooms have been described as “those where all participants – teachers and students alike – have equal right and responsibility to participate in the decision making which frames classroom life” (Apple & Beanne, 1995). Such decisions include curricular scope and focus, classroom participation structures, and rewards and
punishments. Yet such rights and responsibilities are much more expansive than decisions around how classrooms activities happen. More deeply embedded in life in classrooms are the social and cultural structures that maintain relations of power among students and teachers. It is also necessarily part of the democratic classroom that the responsibility for shared power and the protection of marginalized voices and perspectives is also elemental.

It is not hard to imagine why democratic science classrooms have not gained much traction. Science teachers working in urban schools face the formidable task of preparing increasingly diverse students from low-income, minority backgrounds for competitive science careers in a high-tech global economy and for citizenship in a world rich with scientific debate. Science teachers facing this mandate are likely to be young and new to teaching. They often are well prepared in science but lack sufficient preparation in teaching in urban contexts to be successful, leading many to abandon the profession because of feelings of failure and isolation. Furthermore, schooling is framed around traditional models of education, where classrooms limit students to being consumers of knowledge who are expected to memorize facts selected as important by their teacher. The traditional relationship between teachers and students leave students with limited opportunities to participate in classroom decisions. In traditional classrooms, teachers are engaged in a power relationship with students in which they profoundly constrain the actions and choices of students. And yet, teachers themselves are caught in a world where they are expected to be the sole authority, both positionally and intellectually.

In addition to these challenges, little attention has been given to what it means to have the right and the responsibility to participate in decision making for either the individual or the social collective in which they take part. One can envision the importance of rights in classrooms by looking at the case of the respect for students’ intellectual property, the prior knowledge of science that students bring to the classroom from their cultures and home lives, their “funds of knowledge” (Moll, Amanti, Neff & Gonzalez, 1992). Recognition of students’ funds of knowledge is in contrast to common classroom practices where low-income, minority students are seen as deficient in knowledge and skills. To evaluate how teachers value and use students’ intellectual property, one can document when and how often curriculum is situated in students’ life experiences, home life, background, and cultural and social identities – their funds of knowledge.

While the history of research and development done on building democratic classrooms is important, our concern is more with how we – as researchers, teachers, curriculum developers and assessors – come to understand student participation in science learning and its impact on life beyond school. This book is written to describe frames for advancing critical democracy in science education. What it means to bring student voice into science classrooms in ways that foster critical democracy – not only in how teachers and students enact classroom life together, but also in how students (and teachers) are supported in leveraging their school experiences towards building a more just world?

Specifically, we use the ideal of democratic education in science to call attention to ways of being in the classroom that positions youth as important and powerful
participants in their own learning and that of their peers and teachers, and also as members of a larger global society who can leverage their lives in schools towards making a change. We step back to John Dewey to call attention to democracy as “a mode of associated living, of conjoint communicated experience” (Dewey, 1916, p. 87). “Conjoint communicated experiences” seem to be at such odds with schooling today for it calls direct attention to equitable ways of being in the classrooms and moving forth with and through education– a commitment to social consciousness and social reconstruction.

This framing deviates from much of the literature on democratic classrooms where the focus is on how the process of learning itself can become more democratic or in how classrooms can foster deeper understandings of and experiences with democracy. This distinction is important. Democratic classrooms position learning as a dialectic process, where students and teachers learn to “read the word and the world.” This means that one both views the world with a critical mindset and envisions how to advance in the world or change the world into a more socially just and equitable place with and through science, while considering oneself as powerful scientific thinker and doer of science.

Thus, the aim of our text is not to provide a “how to” guide to building democratic classrooms. Such classrooms are locally contingent; there is no recipe for designing democratic science education. Rather, we are concerned with the tools that teachers and researchers might use to foster ways of being that lead to conjoint communicated experiences.

DEMOCRATIC SCIENCE CLASSROOMS: VOICE, AUTHORITY AND CRITICAL SCIENCE LITERACY

Consider a girl, who attends middle school in the poorest congressional district in the country, and is failing science in the fall of 6th grade, but then builds a strong relationship with her science teacher through caring for animals in his classroom during recess and after school. He leverages her animal caring experiences to position her as a science expert during science class. She moves to an A student and refers to herself as “a science poster child.” The experiences that students bring to the classroom and how they are able to voice them towards the creation of empowering science education matters.

Consider another girl, whose has struggled with school attendance and success but who also considers herself a “make a difference expert” because she helped to design and collect over 200 surveys on the local community’s energy practices, analyzed them in excel, and presented the findings to the mayor’s energy policy council, who then made changes in how they distribute recycling bins to Lansing residents. Youth are experts and working with them to author transformational authority matters in building a more just world.

Consider a middle school boy, who likes math but wants to open a t-shirt shop when he grows up. He does not know what engineers are or what they do, and his mom is worried if her son gets too much into science and math he may get picked on. Yet, after conducting an energy audit in his school along with his classmates
and at the local university with energy engineers as a venue for delving deeper into energy transformations, he decides he wants to become an engineer, maybe, one day. Becoming science literate is both about knowing and becoming.

These three stories are real and have been made possible by teachers and students working together to enact a more democratic science education. Our understanding of democratic science education is grounded in critically oriented socio-cultural perspectives of learning, which describe learning as a situated process shaped by the social, cultural, and political environment in which it takes place. As people learn, they move from a peripheral participation in the subject matter community towards a more central position in which they become a fundamental part of the decision and rule-making processes (Lave and Wenger, 1991). These perspectives suggest that learning ought to be thought of as an ongoing process of participation and identity formation, in which learners acquire what is needed for participation in relevant communities of practice, while they construct what kind of people they are and what they aspire to be (Wenger, 1998). In this process, students negotiate forms of participation and identities within the rules and expectations of the worlds they participate in as they engage in their daily practices (Lutrell, 2001).

In this book we draw specifically upon three core conceptual tools that help to frame ways of thinking and being in classrooms that work towards a more just world: Voice, Authority, and Critical Science Literacy. While we briefly describe each conceptual tool below, we note that these ideals are taken up in different ways across the subsequent chapters.

**Voice**

Student voice is not a new concept in education but it is centrally important in democratic science education. Student voice captures the ideas that students’ opinions and ideas matter in both the perspective they hold and in the actions they take (Calabrese Barton & Furman, 2006; Mitra, 2004). Indeed, recent educational research has shown the positive outcomes of school programs aimed to foster youth voice, including teacher learning, reforming school and teaching practices, and for the participants themselves. Tobin and his colleagues have extensively worked with student researchers through cogenerative dialogues that both support teachers in more critically reflecting upon their teaching and learning to incorporate student ideas into their teaching (Tobin, Elmesky & Seiler, 2005). Others have utilized student researchers as well in schools. Fielding (2001) demonstrated that when high school students researched school issues that they identified as important with the goal of providing recommendations for school change, transformative school practices emerged such as the incorporation of students to the evaluation of new curriculum.

At the same time, student involvement in school improvement has also suggested that the incorporation of student voice is transformative to students themselves. Elmesky (2001) reveals how youth gain empowerment through science by having opportunities to expand upon and embrace their embodied resources, like deep knowledge of hip hop. In describing this stance, Elmesky describes in rich, contextual
detail the ways in which she has involved youth as student researchers. Participating students had opportunities to expand their own science toolkits by virtue of participation in the project, and teachers and researchers in this study had their own views challenged and deepened by the youth.

Clearly, voice matters. The science education community does not have a deep understanding of what urban youth experience, potentially care about, or the non-traditional resource they access or the ways that they may activate them. Further, student voices provides active and meaningful learning experiences similar to Dewey’s (1890) notion of “transformed recitation,” which he envisioned as students providing their experiences and ideas and dialoguing with teachers in order to set up new lines of thought and inquiry. Critical visions of education have further claimed that student voices allow children to create their own meanings and become active authors of their worlds, demanding thus that students assume a proactive role in the planning, implementing and evaluating of their own learning (Freire, 1971; Giroux, 1988; Simon, 1987).

Despite these calls, student voices still do not fare well in many American schools: Whether spoken or written, they have too often been reduced to lifeless, guarded responses—responses to the questions and assignments of powerful others, responses formed in the shadow of teacher scrutiny and evaluation. Given the fate of student voices, it is difficult to believe that traditional schooling contributes to the flourishing of individuality and democratic decision-making (Lensmire, 1998, p. 261).

**Shared and Transformational Authority**

In education studies, authority is often framed through reason or position without deeper consideration of how such positional authority is situated within cultural and social norms that can be oppressive (Pace & Hemmings, 2006). This perspective distinguishes authority based on how one is endowed with institutional power by virtue of their status (position) and knowledge possession (reason). In the case of teachers, authority is assumed based on status and knowledge where teachers have “authority both in the sense of having the power to direct classroom activities, and in the sense of having the knowledge that the students need to acquire” (Buzzelli & Johnston, 2001, p. 875). The authority of position and reason are particularly compelling in science class because science disciplines are usually taught and perceived by teachers and students as having “well-defined, unequivocal answers and solutions, as well as the unambiguous rules that students typically encounter in the exact and biological sciences” (Raviv et al., 2003, p. 19).

The limitation of this perspective on authority is that a “school’s preoccupation with the authority of reason and of position can cause teachers and students to ignore a type of authority lying at the heart of action and performance: the authority of experience” (Munby and Russell, 1994, p. 97).

Our work with youth suggests that although the authority of position and reason play out in powerful ways in school science -- and that one must be attentive to how it gets constructed, there are other powerful ways in which youth purposefully seek to enact authority in schools in ways that are transformative. Indeed, we have
witnessed youth who have sought ways to enact their own authority against the tide of position and reason. As minorities living in a majority-controlled society, coming from low income families, and students in schools that do not appear to value their experiences and knowledge, many of the youth we work with have not been perceived as possessing authority based on position or knowledge. These students were neither in authority, nor authorities themselves.

Democratic science teaching employs a different slant on authority and its relationship to classroom communities. We refer to this kind of authority as both shared and transformational. In this framing, authority is not based on position but rather on how and why one leverages knowledge and experience towards bringing about social good. Here, we recognize authority as relational, and bound by social and cultural structures that define relationships. It is enacted or exerted directionally – with particular goals in mind, though such goals are not always conscious. What contrasts this kind of authority with the authority of position and reason is the idea that all individuals possess authority because it is formed and informed through the continuous and interactive nature of experience rather than an institutional hierarchy or an epistemic truth. This authority that we describe here is similar to Pace & Hemmings (2006) idea of emancipatory authority or “authority that serves the education of all students as well as the democratic values of justice, the common good, participation, and the freedom to question” (p. 26). However, it also calls attention to the role of students in the process and in the desire to use personal and scientific knowledge and experience towards change.

Critical Science Literacy

A number of authors have explored the idea of scientific literacy, producing various definitions of this concept (Laugksch, 2000). There have been growing debates on whether the science education community’s focus on science literacy should also explicitly incorporate notions of citizenship and democratic participation (Hobson, 2003). It is argued that schools could be more centrally concerned with “civic” science literacy (Miller, 2002), which focuses on (1) scientific understandings of basic foundational ideas like matter and molecules as well as on the nature of scientific inquiry, and (2) the development of a regular practice of consuming science information through reading about and evaluating scientific ideas as they relate to the public sphere. This view of science literacy is not drastically different from those ideas put forth by Project 2061 (Benchmarks for Scientific Literacy, 2003) when this project first introduced “science literacy” to the science education community’s lexicon in the 1980’s. However, the emphasis (or balance) between “what” one should know and “why” this knowledge ought to be taken up in daily life differs in civic science literacy, with more emphasis on how and why public consumption of science ought to take place.

Despite calls for science literacy or even civic science literacy, it has become common knowledge that most pupils in the US school system fall short of this goal. Both Project 2061 and National Science Education Standards (National Research Council, 1996) argue for a stance on literacy and science that combine content,
INTRODUCTION

inquiry skills, and habits of mind but do not necessarily offer insights into how a powerful combination of these three critical areas ought to frame participation in a democratic society. While both of these major policy documents carefully state the importance of conceptual understandings in making sense of human action and interaction, little attention is given to what this might mean or look like. Science should be taught in a manner that “inspires student understanding and enthusiasm, and is relevant to the cultural and social needs of students and society” (Hobson, 2003, p. 110). We believe Hobson advances how we ought to be thinking about science literacy; his point, however, stops short of engaging the idea that learning is about agency, about transforming one’s world.

Learning, thinking and knowing involve “relations among people in activity with, in, and arising from the socially and culturally structured world” (Lave & Wenger, 1991, p. 51). Yet, not all situations are equally valued. Thus, any instantiations of science literacy must also attend to how “situations are themselves confluences of widely distributed streams of activity” (Nespor, 1997, p. 169). Indeed, part of science literacy is a process of developing a critical consciousness with respect to context, with the power to transform reality, positioning the learner as a growing member of a community, with expanding roles and responsibilities (Freire, 1970). From the perspective of democratic science education, science literacy must therefore be attentive to the roles that youth generate or accept for themselves within science-related communities, their reasons for participating in particular ways, and the relationship they perceive these roles have to the knowledge and practice of science. Here we view these articulations of what it means to be successfully engaged in science (i.e., successful science learners) as both products of and contributions to one’s location in the world.

We refer to this kind of science literacy as critical science literacy because without access to the content, practices, and discourse of science, youth may not have opportunities to develop rich repertoires of science knowledge and practices for engaging in the world in empowering terms. Yet access alone does not account for how youth might learn to understand what science is, to utilize science for personal and social transformation, or to engage in public discourse and debate. Critical science literacy not only promotes all important elements of science literacy as advocated by the American Association For The Advancement of Science [AAAS] (AAAS, 1990) but it also embeds essential skills to participate in a democratic society in fair and just ways. Instead of just attending to “what” individuals need to know, critical science literacy challenge the socio-political context of how and why youth are taught to engage science in the current system, thus challenging the functional view of science literacy that promotes economic growth at the cost of poor and marginalized groups (Calabrese Barton & Upadhyay, 2010).

KATE AND HEATHER: WORKING TO INCORPORATE VOICE, AUTHORITY AND CRITICAL SCIENCE LITERACY

To help illustrate our points, we present two stories of fairly new science teachers, Heather and Kate, and their attempts to enact student voice, authority and critical science literacy in their science classrooms.
Kate

Kate was in her second year of science teaching. After trying out different career options as a computer engineer she had gone back to school for a masters degree in education because she wanted to make a difference. She chose to work in New York City despite having grown up in the suburban south because she felt this was where she might be able to give the most. Pivotal to her decision where her own high school experiences:

In my high school, it was a magnet school, but it was — it put the magnet school in a high school because the high school had low scores and a large, low-income, minority population. And so they put a magnet school in to make — to bring up the school, but in my classes, I mean, my classes were not mixed. Our graduating class, the high performing students, were all magnet kids from other cities, and so I saw that, and I thought, “This is messed up.” And I don’t know, I thought there was so much room for improvement in public schools already, so that’s what I wanted to do.”

Kate believed that school science was about bringing together “knowing and doing” in ways that would both open up opportunities for youth in their future lives but also help them in the moment. Making these in the moment connections were important to Kate because she felt that this would help her students see the relevance of science. Her students were not only members of groups who have been historically underrepresented in the science, but also the students in her school had not, as a set, fared well academically in science or other subjects. She wanted her students to feel inspired by science, to use science to critically question their life experiences, and make solid connections between home and school. Science was the natural subject area to make connections because as Kate said you can make science out of any problem.

Yet Kate acknowledges that learning science in ways that promote critical literacy, connections, and inspiration is challenging, especially when you are not insiders to your students families or communities. After her first year of teaching she realized that she did not have all of the “answers.” She acknowledges a big “ah ha” moment that fundamentally transformed her teaching. During a unit on forces and motion, Kate introduced motion probes to the students so that they could measure and graph the movements and velocities of small cars as part of their lesson. When she first introduced the probe wear Kate seemed surprised to see that the students wanted to play with the probe wear rather than use it to conduct their assigned experiment. Instead of getting frustrated with what appeared to be “off task” behavior, Kate made an “on the spot” decision to modify her lesson. She told the students they could conduct whatever motions they wanted in front of the motion probes and record their data, that they would talk about later that day. They would conduct the experiment the next day. Many of the students could be observed dancing in front of the probes, laughing, and recording their dance movements graphically with the probe wear data. While the class did get back to the car experiment, it took 2 days rather than one because of the level of interest students expressed in understanding the physics of their dance movements. In speaking with
Kate after the lesson she said she was surprised she hadn’t thought that the students might simply be excited to use the probes since they had never been introduced to the technology before. She also said that she learned a valuable lesson that day – that even reform minded curricula grounded in the students’ experiences may still not really capture your own students’ experiences. As teachers you have to constantly be paying attention to the cues that your students give you.

Student voice mattered a great deal to Kate but so did allowing them to have epistemic authority in her classroom. In her second year of teaching, Kate had called a parent to discuss the students’ lackluster grades. When the parent suggested that her son would be interested in doing a science fair experiment, Kate decided to design a science fair for the entire school. The fair, she felt, would meet both the needs of the District Exposition Project and to provide students an opportunity to share their work with the school and neighborhood community. Kate decided that the crux of the science fair project would be an experiment: Each student would conduct their own investigations and present them in the standard demonstration format for the school to view. She wanted the students to have authentic projects but she also wanted to offer her students structure, given that they had not participated in such an event before in that school.

Kate offered three organizing structures to support students in developing their projects:

- A list of experiments the students could select from, based on her own research into experiments that were “inexpensive” and “simple” and could be measured or rated or quantified.
- A guideline for preparing the research paper and poster.
- A series of worksheets aimed at helping students through each of the primary steps in their investigation (i.e., developing a hypothesis, designing the experiment, etc.).

After offering an initial week’s work of intensive instruction/activity on the science fair projects. She also provided one class period a week for about 9 weeks to allow students to work independently on the project while also having access to school resources. The science fair was transformative for both Kate and the student, Quacey, as we describe below.

Quacey, who was relatively new to the country (his family having moved from Ghana 1.5 years previous), spoke with a marked accent, and was well liked by his teachers and his peers. Though students sometimes made fun of his “big lips,” Quacey was tall and confident and used those qualities to win and maintain friends.

Quacey loved to build. His father is a construction worker and one of his brothers is a construction worker as well. He says that in his free time, he takes out all his toys, which are mostly screwdrivers and motors, and builds cars. Quacey was also rather articulate about the science behind the things he built, typically drawing upon his experiential knowledge to explain how things work: “Well the [car] motor, uh the motor got like magnet inside of it… It like a magnet… it got metal around it and it got magnet and it got like this thing inside…”

The first weeks’ work on the science fair was marked by Kate reviewing with the students what a good science experiment was and the guidelines for the project.
She handed out the list of experiments to choose from and gave students time in groups to investigate the list and to settle on an idea. She also offered the students a worksheet to guide them through how they would transform the research topic into an experiment. However, despite his intense interest in doing a science fair project, Quacey was unsatisfied by the list because his topic of interest was not included; he wanted to build something and he was keenly interested in space exploration. When he explained this to Kate, she responded by saying, “then come up with a proposal!” Quacey and his partner first sought approval by presenting their topic – building a Mars Rover – to Kate, in both written and oral formats. They demonstrated a connection to a topic previously studied in class (forces and motion) in a way that validate their topic and showed it as worthwhile and scientific. In their discussions with their teacher they referenced the classes previous study of the Mars Rover, a topic his class briefly covered months earlier during a NASA rover rendezvous with Mars. They also presented written evidence for scientific sources of information they could draw upon (i.e., NASA website and science books), and they showed knowledge of key science ideas involved (i.e., pressure and lift off, H2 as fuel, and electricity) (see figure 1.1).

They also framed their building project as a design experiment, by offering a hypothesis that the rocket would “vibrate and the light would be flashing and the perpeler [sic] will spin” when it moved across the planet surface (see figure 1.2).

While Kate conditionally accepted the boys’ idea, she was firm in her resolve that their project needed to be adapted in order to be “more experimental” – in other words, she wanted them to be able to offer evidence that their rocket or rover was a success or failure. As a result, Quacey and his partner continued to

Figure 1.1. Quacey’s rocket design.
negotiate aspects of their project to maintain the support of their teacher (i.e., how to frame their project as an experiment) while holding to those dimensions of their project most important to them (i.e., building something). They adapted two key teacher suggestions: they referred to their Rover as a “model” and they modified their protocol to include multiple tests in order to offer quantifiable data. They also decided upon two different models in order to compare data that would allow them to build two different designs.

As a result of these strategic negotiations, Quacey and his partner were able to maintain an emphasis of their project on building but at the same time learned to view building as a process of design and experiment, and they created an opportunity to educate the rest of the class on this topic. They were able to keep as central their identity as builders but also continued to be science students in good standing. Through the topic of building they were able to validate their efforts to draw upon nonschool-based resources for completing the project, including parental expertise on building and using the internet, parental views on aspects of science that are important, personal experiences building, and social alliances for drawing in various forms of individual expertise (i.e., the group expanded to four students, and one person was the artist to create the final model sketches, another the lead builder, while two others the researchers and writers).

In other words, they found a way to balance the school expectations, knowledge or resources with their individual interests. They used the project to have their interests a valued and official part of science class, to build and maintain the kind of social relationships that mattered to them, and to still be viewed as smart and scientific by their teacher. They were lucky – One possible reason why they were able to co-opt this science event is that they had a teacher who wanted also to value what they brought to the classroom and was willing to “negotiate” with them to make it happen in a way that met her needs and expectations as teacher.

It is no surprise that in setting up the guidelines for the science fair that Kate bounded the science fair assignment by requiring students to conduct an experiment, rather than allowing them to make a model of something, like a volcano, which is
often observed at science fairs at this grade level. The science fair “had to be about” solving some problem or issue. It was also not surprising then, that Kate also came up with a set of “research projects” that students could undertake that directly related to the content covered in school that year. Before she introduced the science fair to her students, I (Verneda) observed her spending hours and hours researching the content covered in the school that year so that she could provide students with examples of projects that connected this content to their students lives. She ended up distributing a list of research questions that students could select from based on her research.

Heather

Heather was an 8th grade science teacher at the School for Social Change (SSC) in New York where she has taught middle school for five years and particularly developed a materials science class which draws on current topics in physics and chemistry. SSC is a small public school that opened in the Sunnyside Park neighborhood of New York City in September 2004. It was part of a second-wave of small new schools opened with the approval of three authorizing agencies – New Visions for Small Schools, the Gates Foundation, and the New York City Department of Education — as well as a series of other non-profits such as the Annenberg Foundation and the Open Society Organization.

The school opened with seventy-five sixth-graders and seventy-five ninth-graders; now, the school serves 525 students, ranging from grades six to twelve. The school is housed in a campus that it shares with four other small schools; the existing large school in the building has been phased out.

Heather was drawn to SSC because she had flexibility and freedom in how she taught. She even referred to the school as having a culture of democracy. She situated her class in what students thought, though she would generally design the framework for what happened in class. She saw SSC as a place where she could visit other teachers’ classrooms to learn. One thing she hoped was to personalize to individual students the content and skills she normally taught.

Heather believed that democracy in a school prepared students to be active citizens, and in order to be active citizens, they should vote for order of units, the type of final project, and the type of field trip to take. She also thought they could help with classroom management. Thus, as a teacher, Heather is deeply conscious of the importance of incorporating student voice in her classroom as well as sharing authority with the students.

In the fall of 2007 and spring 2008, Heather put a new set of democratic teaching ideas into action. First, as a prelude to this project, Heather and her students independently wrote and/or drew their conceptions on how democracy fits into a science class. Second, she and three of her student helpers (Dale, Kristy and Trisha) polled her class for a science activity they would most enjoy in the future, and designed a plan to enact this idea. Then, Heather and the students designed a contract for participation during dissection and a worksheet that would support students in learning a variety of anatomy and physiology while dissecting the frog. All of these processes involved Heather’s three student helpers and the voices of students in her
different science sections, making the entire process democratic, in that it included subject knowledge but also student experiences and ideas. Her students were co-constructors with Heather of both the expectations and climate for the science classroom, as well as the science projects they wanted to engage in.

The class had chosen frog dissection as their preferred activity even though the course covered the realms of physics and chemistry. They wanted to step away from their regular classroom activities for a day and act like “real” scientists conducting an investigation. It was also something the students were very interested in doing, and Heather was supportive of their decision. In addition to designing how the activity would proceed in class, Heather and the students also identified their roles in the classroom and designed an assessment to figure out whether this type of activity had influenced their peers’ engagement and long- and short-term interest in learning science.

From exit interviews and analyses of the assessments that the participants crafted, many students in the class in which this dissection happened learned about frog anatomy, physiology or evolutionary history – all of which they were able to communicate. The participants themselves seemed to most benefit from the experience of planning and executing the lesson. Their knowledge was refined and they had good ideas about how to dissect and also how to help their peers in this process.

For example, students in exit interviews made some the following comments: “One thing that I noticed is that frog parts are similar to human anatomy. That suggests to me that humans and frogs may originally have come from a similar place.” In a community where evolution is not a popular explanation for species diversity this comment particularly stands out as an important marker of learning. Several students talked about the idea “of adaptation” and how animals like frogs develop body parts suited to their environment. This is an important evolutionary concept that students will need to know in high school. Students learned a variety of new dissection skills that would help them in future activities in high school labs, e.g. one student talked about having the flexibility of using the scalpel, while others talked about their surprise when they cut into the frogs and there were different layers of texture before diving into the inner anatomy. Two features the students found particularly fascinating were the nictitating membrane on the frog eyelid and the reverse attachment of the frog tongue. This was definitely new knowledge and provides a new example of how student choice can lead to peers engaging in high-level detailed observation. In addition to knowledge of laboratory safety and procedures, Heather reported the following as New York state 8th grade science standards she addressed with her students through their lesson:

<table>
<thead>
<tr>
<th>Standard 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1g Multicellular animals often have similar organs and specialized systems for carrying out major like activities.</td>
</tr>
<tr>
<td>1.1h Living things are classified by shared characteristics on the cellular and organism level. In classifying organisms, biologists consider details of internal and external structures.</td>
</tr>
</tbody>
</table>
This is an example of how Heather’s students were gaining critical science literacy – learning rigorous scientific knowledge that they were invested in.

A few students commented that the frog activity “really” made them feel like scientists because they were actively doing and exploring and they had independent choice. It made them feel as if they were acting like scientist, a field in which Heather’s students are vastly under-represented at all levels. Heather’s students were able to enact and experience critical science agency, both in being a confident scientist from a minority background and in shaping one’s classroom. New roles for certain students were also created so that authority is shared between Heather and her student-helpers. Heather said: “Even students who would lose focus because of what other students were doing around them would eventually come back to their work without too many reminders from me.

However Heather’s students helped choose the topic of the day, organized its outline, made sure the material was content-rich, provided clear safety guidelines and reserved spaces for student choice in the activities. This process was critical because student power was integral to the design and execution of the day. The roles and reactions of the three students are described below.

Heather reported that “It made me realize that I can have students helping one another out; being “teachers” more often and it could be productive,” suggesting that the experience shifted her view from that of a classroom where teachers kept knowledge and power to students supported to be experts could have shared authority with teachers, to the benefit of all students. Heather’s story described how a teacher can create many routes to democracy in her classroom, how this environment empowered youth in “critical subject agency” – deep knowledge, more engagement, challenging under-representation, and tackling issues of equity and power through subject knowledge. The goal was to show how democratic science teaching creates a hybrid between traditional and progressive educational practices and a third space in which low-income, minority students can experience success, voice and choice in their science learning.

LOOKING AHEAD

In Kate and Heather’s classroom we see, in her collaboration with students, elements of democratic teaching emerge in that she shared authority with students, cultivated student voice, and sought to support students in bringing their “funds of knowledge” (Moll, Amanti, Neff & Gonzalez, 1992) in choosing their activity, and challenged traditional classroom power structures by being flexible and student-centered in her teaching approach. Building student voice into her classroom, sharing authority with youth, drawing on students’ lived experiences, giving students structured choices were central to her identity as a teacher. In a world of standardized test pressures, poor pay and classroom management challenges, co-creating her science class with students helped Heather keep their needs and interests at the forefront of her priorities. Because she cared about what students want and think, youth were often in her classroom at lunch and after-school and tried to excel at the complex scientific knowledge- and inquiry-based tasks she posed to them. Likewise, Kate
demonstrated sensitivity towards student interest and voice, taking their ideas and suggestions seriously in both the probes activity and science fair projects.

With Kate and Heather, we can see how these themes of community and shared authority are important to her teaching. Perhaps more important is why these goals matter to them and to the teachers in the following chapters. As discussed before, critical science agency continues to be a key theme in a model of democratic science pedagogy. In Heather’s classroom as in the ideas presented by both groups, students acting as agents of change as the goal of democratic science pedagogy—shaping what happens, what is taught and how teaching and learning occur. Students’ had authentic opportunities to engage science in ways that validated their voices and perspectives. In her class, a significant and formative factor in her classroom practice was that students took on more equitable standing with their teacher and had more voice in the curriculum and structures of their classrooms.

Schooling can be viewed as preparation for real-life but what that means is that students are expected to conform to normative standards. Young people spend so much of their time in school and this context shapes so much of their intellectual and social lives—it seems only respectful of their time and experience to consider school an important space that they can shape in their own image.

Democratic science pedagogy has the potential to shape learning outcomes and science engagement and that these possible impacts are worth exploring. Both teachers and students in this study either demonstrated or articulated enthusiasm for science classrooms reframed from a democratic context as holding the possibility of bringing out the best in students: motivation, a desire to learn, an energy for being engaged in science content and classroom debate. Further exploring the nature and impact of democratic science teaching has the potential to address issues of social justice in science education and science itself by empowering teachers and students in traditionally marginalized urban schools to craft science and its instruction in ways that feel meaningful and relevant while opening doors for students to success and engagement in science courses and careers, and helping students develop science knowledge, which they can use to make change and redress power differentials in their lives.

OVERVIEW OF THE BOOK

The book follows the following structure. In Chapter 2, Jhumki Basu interrogate what we might learn about equitable and empowering teaching by listening closely to youth. The chapter draws extensively upon the experiences of two of Jhumki’s students and their work in her high school physics classroom to offer a more expansive lens for the outcomes of science education. This chapter specifically takes on the construct of “critical physics literacy” to argue that the learning outcomes of democratic and empowering science teaching should include not only deep understanding of the knowledge and practices of science but also a science identity that fosters critical engagement in science towards building a better world.

Chapters 2, 3 and 4 delve into the processes and outcomes that frame democratic science education: agency, authority, and empowerment. In Chapter 3, Tara O’Neill
examines the relationship between student ownership of science and student agency. As Basu does in her work on critical physics agency, O’Neill calls us to examine more carefully what science learning communities look like such that they foster authentic ownership of ideas. In doing so, she makes a case that agency in science is a more powerful measure of student learning because it positions youth as producers and users of scientific ideas, rather than merely consumers.

In Chapter 4 we interrogate how youth purposefully merge their everyday discourses with those of science in order to transform what it means to be an expert in science – making critical to expertise the ability to talk across communities of practices in ways that are meaningful to the members of different communities, whether it be scientists or neighbors.

Chapter 5 takes us back into classrooms to look at how elementary children appropriate democratic practices in science teaching and use them to form their own instantiations of empowerment and what it means for teachers to recognize these in public ways. Each of these chapters provides us with a rich snapshot of youth-in-action, taking the reigns to illustrate to others what it means to be an empowered learn and expert in science.

Chapters 6 and 7 return to the question of teaching and the role of leadership. What can and do teachers do to foster empowering and equitable learning environments among their students, and how are these practices culturally situated. In Chapter 6, Gale Seiler presents the story of a young pre-service teacher in post-apartheid, rural South Africa who sought to redress issues of injustice in his science classroom by enacting specific teaching strategies including incorporating ESL language teaching strategies and incorporating cultural congruence. In Chapter 7, Christopher Emdin addresses the ways that the concept of citizenship, through the use of cogenerative dialogues, coteaching and cosmopolitanism (The three C’s) as a triad of tools, can improve student experiences in the science classroom and provide students and teachers with the agency to address inequity both within, and beyond the classroom.

Finally, the last chapter, Chapter 8, examines cross cutting themes across the text and focuses on how to re/frame the problem spaces of equitable and empowering science education.
JHUMKI BASU, ANGELA CALABRESE BARTON, NEILE CLAIRMONT AND DONYA LOCKE

2. YOUTH VOICES

Challenging the Outcomes of Science Education

In this chapter, we present the experiences of two of Jhumki Basu’s students and their work in her high school physics classroom to offer a more expansive lens for the outcomes of science education. This chapter specifically takes on the construct of “critical physics literacy” to argue that the learning outcomes of democratic and empowering science teaching should include not only deep understanding of the knowledge and practices of science but also a science identity that fosters critical engagement in science towards building a better world. This chapter is based upon her publication in Cultural Studies in Science Education.

About half way through the school year, the students in Jhumki’s ninth-grade conceptual physics course were presented with an opportunity to co-design a lesson for their class. The option was voluntary, but the teacher presented the opportunity to all of her students as one way to incorporate students’ voices and experiences in her planning and teaching of physics. One student, Donya, took up the challenge because, as she described, she wanted to connect what she was learning in her physics class with her interest in becoming a lawyer, and she wanted her peers to be able to make similar connections. Donya initially told Jhumki that for her lesson plan she wanted her peers to engage in a class debate on the gravitational pull of black holes.

In describing her reasons for selecting the debate format and this topic, Donya cited a past experience from physics class, where she and her peers argued about the impact on the world of Einstein’s E=mc² equation. Donya was excited by the idea that a high school science student could take a position on important scientific ideas and could argue about the impact of an idea developed by someone as famous as Einstein (See Figure 2.1 in which Donya is describing her perspective on debate in science). She also liked the idea that debates on controversial topics in science do not necessarily have right and wrong answers but that they require students to develop and defend a stance. Donya thought that if she set up a debate then her peers would have a chance to think through ideas instead of repeating back what their teacher construed as the “right” answer. Donya thought that a debate would better prepare her for her future as a lawyer. She also engaged in a sophisticated view of science as tentative, rather than a canon of static truths.

With help from Jhumki, Donya expanded her debate from a focus on the gravitational pull of black holes to include the impact of dark matter and energy on
Figure 2.1. Donya discussing the role of debate in science.

the future of the universe. Donya wanted each student to take responsibility for understanding the material, so she instituted a requirement for each student to write a paper on the topics of dark matter and dark energy during the week leading up to the debate. See Figure 2.2 for examples of material that Donya and Jhumki created together for the debate.

On the day of the debate, Donya acted as the facilitator and judge. Based on research they had conducted in response to questions such as: “What do scientists think dark matter is?” or “What is the evidence that the universe is accelerating apart?

![Handouts for the debate created by Donya and Jhumki.](Image)

**Court Room Trial of Le: Matter and Energy:**

*A Modern Physics Trial*

Co-Designed by Donya Locke

**Structure**

- Trial Monday 6/6
  - 2 courtroom trials
  - 2 teams per trial: one defending, one prosecuting
  - 6-7 people per team
  - Judge and jury made up of students and teachers evaluate the teams
  - Winning teams get a pizza party (we know we owe you one anyway)
  - Counts as test for this unit

**Timing** (40 minutes total, 5 minutes to test to next debate)

1. Opening Statement Team A (2 min)
2. Opening Statement Team B (2 min)
3. Main Arguments Team A (6 min)
4. Main Arguments team B (6 min)
5. Preparation for Rebuttal – both teams (5 min)
6. Rebuttal (Response from Team A) (5 min)
7. Rebuttal (Response from Team B) (5 min)
8. Closing Statement Team A (2 min)
9. Closing Statement Team B (2 min)
10. Judge and Jury Evaluation (5 min)

**Trial Question**

*Dark matter and dark energy have been accused of pulling apart the universe so that it will become a cold, distant place without life and light. Is there evidence to convict dark matter and dark energy of this crime?*

Figure 2. Handouts for the debate created by Donya and Jhumki.
Figure 2. Handouts for the debate created by Donya and Jhumki. (Continued)

How convincing do you think this data is?,” teams of students presented pro and con arguments for whether dark matter and dark energy were pulling apart the universe. Each team had five minutes to present an opening statement and then faced five minutes of questioning from the other team followed by a few minutes to respond to questions. At the end of the debate, students voted on what they thought was the best answer to the debate question.

Donya created rules of conduct for the debate, for example: “No put downs such as ‘Your argument is stupid’” and “You must raise your hand if it’s not your time to speak.” She also created a rubric for the debate, which she and Jhumki used to evaluate whether the groups participated in the debate, how respectfully they were to other teams, and the level of detail and specificity of answers in their written report. For example, one criterion in the rubric was: “Team is inspiring and convincing in their argument. They provide lots of EVIDENCE for their position, no just opinion.”

Despite what Donya and Jhumki considered to be detailed planning, Donya felt that the debate was unsuccessful. In her particular ninth-grade section, she felt that the students were not as actively engaged as she had hoped. Within groups, there was confusion as to who was speaking and in what order. Students did not seem to understand how to link the content they had learned on dark matter and energy to an evidence-based stance on how these shape the universe. Donya’s observations
of these problems inspired her to envision ways in which class could be altered to better support students in learning to make arguments. For example, she felt that the ninth-graders might benefit from public-speaking lessons. Also, Donya thought that students needed practice with small group debates before engaging in a full-class debate.

The following year, Jhumki incorporated Donya’s debate in her ninth-grade physics class. When she prepared students for the debate, she used Donya’s suggestions. She had students discuss what it means to speak well in public and had them practice presenting their stances to each other, prior to the final debate. The students also took on personas of religious leaders and physicists, which helped them engage in the idea of interpreting information from different perspectives. Far more students participated successfully in the debate that year, as a result of Donya’s reflections on how to support students in debating complex, controversial science topics.

Donya’s experiences helping to set up a class debate on dark matter and energy are a glimpse into how she helped to create a place of engagement in school science that supported who she was and wanted to be. Donya made use of the opportunity to plan a lesson in collaboration with her teacher to experiment with the idea that learning science was not always about right and wrong answers, but could also be about arguing science ideas, in evidence-based and reflective ways.

The vignette about Donya suggests that she was an agent of change in how her physics class was structured. Freire (1970) argues (and we agree) that a primary purpose of education is to support students in becoming agents of change. Change is an interesting concept because it could mean larger social change or smaller incremental change. In the case of Donya’s experiences crafting a debate on dark matter, we see, if for a moment, a young woman who begins to understand what it means to think and know scientifically and to use the opportunity of lesson planning to help her peers to see that too. Given that school science for many youth is an experience in getting right (or wrong) answers, Donya sought out significant changes in how science is learned, albeit on a small scale in her personal classroom context. Donya certainly experienced challenges in enacting her lesson – things did not turn out in the ways she had planned. But her reflections on what went wrong moved her and her teacher to better understand how students learn and what supports they needed to engage debates.

For Donya, and for other students in our larger study, their experiences in physics simultaneously engaged them in content knowledge and education for change, or what we refer to as “critical science agency.” In this chapter, we investigate when and how students developed “critical science agency” in a physics context and what this meant for their deeper engagement in physics learning.

STORIES OF DEVELOPING CRITICAL SCIENCE AGENCY
IN A PHYSICS CONTEXT

We begin this section with Donya’s and Neil’s stories of critical science agency. For both students, the story is their own personal narrative, which they wrote themselves. For authenticity purposes we leave their narratives in the first person, but italicize them to offset them from the rest of the text. The purpose of these stories is to introduce
the readers to the participants, as they describe themselves in their own words. Following the vignettes we reflect upon their stories to unpack what critical science agency can look like in a high school ninth-grade conceptual physics classroom.

Neil’s Story

My name is Neil, and I attend the School for Social Change, which is located in Brooklyn, New York. I am an eleventh-grader. During my freshman year of high school at the School for Social Change I met this wonderful teacher named Jhumki. She taught me science for two years in both ninth- and tenth-grade. Jhumki came to me one day and asked me if I would be interested in robotics and the New York/New Jersey Robotics tournament. My first response was “No. I won’t be able to build a robot. It’s too hard.” Then after two-three weeks I told her “Yes, I would love to learn about robots.” And from there my future and goals were to build robots for the military and Homeland Security. My main goals were protecting soldiers and finding terrorists. Robots can improve the life of my fellow comrades dying in the combat field. My cousin served in Iraq for one year which was very painful not only for him but for his parents. However after high school I plan to join the army. “Hooahhh!!!”

Besides joining the army I have many other goals I want to achieve in the near future. I am a student who is very interested in robots. I have participated in the New York/New Jersey Robotics tournament for 3 years now. My teammates and I came up in the top 10 in the competition where we had a big challenge to face ahead of us.

I also learned about robots through the ninth-grade science fair. The ninth-grade science fair was something I will never forget because the science fair showed and taught me a lot about how seriously I take robotics. For the science fair I built a robot that went back and forth (see Figure 2.3) with a mechanical claw attached to it, without any remote control – just in respond to its surroundings, based on a

Figure 2.3. Neil and his robot at the ninth-grade science fair.
program I downloaded from a computer into the robot’s brain. The skills I have learned with regard to robots are to build a powerful robot that will be able to move around and is aware of its surroundings. I have learned to attach sensors so that the robot can be alert regarding what’s in its sight and programming in Virtual C, which is a very difficult thing to do. The reason why it’s difficult to do is because you must write the correct program in order to have a very successful mission for the robot. (Any slight error will cause the robot to fail its mission). I increased my programming skills by taking a two-day workshop that introduced me to the robot before the first year I started the competition and by reading a manual on programming and playing around with the programs.

Donya’s Story

My name is Donya Locke, and I am about to become a senior this year at the School for Social Change. I am the type of student who likes to be challenged and I find no joy in doing work that is fairly easy. I tend to get very frustrated when I know right off the top of my head what I am supposed to do. I like to think of myself as a strong and intelligent person. Therefore I often try to go beyond my ability. I set certain goals for myself that I try my hardest to accomplish. I also love to get involved in many different activities. I feel that my brain takes me beyond where I should be and that’s a good thing.

Since I was in Junior High School, I have never been a big fan of science. However, I try to get involved with various aspects of it because you can really realize that it’s very interesting. At this point, I am linking even more because it’s growing on me, which helps me understand it better.

In my ninth-grade year I created a science lesson for my peers. For extra credit I helped my physics teacher plan a lesson on black holes. The purpose of this lesson was for the students to learn more about dark matter and more specifically black holes. It was also an opportunity for them to be able to argue for and against the topic. At first I did not know what I was doing but I used my career goals to help get through it. When I grow up, I want to become a lawyer so what I decided to do was have a debate. One question was “If any object ever gets sucked into a black hole will it be able to get out?” So we split the classroom into two groups, one side said no and the other said yes and they had to use research to prove why they are correct. In this lesson, my role was the facilitator and the judge.

The classes did very well however they had trouble using the information they had as arguments for the other side. Another set-back was that students chose not to participate but instead kept their heads down and were quiet after entering the room.

CRITICAL SCIENCE AGENCY AS AN ITERATIVE AND GENERATIVE PROCESS LINKED TO IDENTITY AND THE STRATEGIC DEPLOYMENT OF RESOURCES

Defining Critical Subject Agency

Critical agency has taken up an important place in educational research framed around research on issues of equity and social justice. Whereas the vast majority of
research on critical agency tends to focus generally on students’ abilities to build critical awareness and engage in acts of social transformation, a subset of this work is more deeply grounded in how participation in subject matter communities frames one’s enactments of critical agency. For example, in a study of urban sixth grade mathematics students, Turner and Font (2003) characterize critical mathematics agency as viewing the world with a critical mindset and engaging in action aimed at personal and social transformation through developing deep and rigorous understandings in mathematics.

Next we look across both stories to describe how critical science agency in a physics context emerged as the expression of identity and the strategic deployment of resources and identity.

Neil. Neil’s story in this study begins with him arriving from St. Lucia and struggling academically and socially in his school. It unfolds with him taking on ever-expanding challenges in physics, computer science and engineering, building relationships with teachers and students and establishing himself as an expert and agent of change at his school.

Neil’s story suggests that the expression of critical science agency – Neil identifying himself as powerful science thinker and doer in ways that advanced his participation in his community – was connected to the expansion of his identity (taking on the roles of expert and teacher and building social networks with peers and adults). In Neil’s story, we begin to see how a young man worked with his teacher to create opportunities to expand his knowledge of robotics, and have that knowledge mean something for his conceptual physics class. In the process of doing so, he was afforded opportunities to draw upon his deep understanding of robotics, electricity and forces and motion, to build a new identity in his science class as an expert in robotics, and to use that knowledge and identity to transform some aspects of his own life and his physics classroom.

Neil—an expert in robotics. In the weeks before the science fair, Neil sat at the back of class at a table separate from his peers. Each day, he spread out across the table the parts of his robot and a dedicated laptop and worked on either building the physical structure of the robot or programming its movement. Students visited his construction area/design site during these weeks to look at his robot as it developed and to ask him questions about his next task. He rarely spoke in class except to ask his teacher for help with his work. This was in sharp contrast with Neil’s usual behavior – prior to the science fair unit, he often moved about the room, participated in name-calling and arguments with his peers and his teachers, sometimes stared and rolled his eyes at students, burped loudly in class, and called out unexpected and often rude comments. In an interview, Neil described his behavior as a purposeful decision to “act dumb.”

Learning programming required Neil to develop expertise. He had to read from manuals, test out sample programs, and spend hours trouble-shooting with his physics teacher and with mentors at the local university that sponsored the robotics competition in which he was involved. Revising his robot time and again taught Neil to build a strong, self-contained robot.
Neil’s experience with robotics also helped to reinforce some of the concepts covered in his conceptual physics class. As he constructed his robot, Jhumki observed Neil review and enact schematics that involved concepts about electricity such as charge, current, voltage, resistance, diodes and more. For example, he studied the circuit board associated with his robot and identified parts of electronic circuits. He had to find batteries of different voltages for different appliances. In his science fair poster, Neil displayed his attempts to craft the kinds of programs he had wanted to create for his robot and the challenges that he faced in this process. He provided this information as an example of hypothesis-testing through data collection in that he tested programs he thought would work and modified them based on his results. In this sense, Neil gained literacy not just in physics content but in the open-ended inquiry aspect of being a scientist.

On the day of the science fair, Neil placed his robot in the hallway on top of a game board he had drawn on a portable white board. When Jhumki came to look at his project, there was a crowd of students around him watching him run the robot as it collected colored plastic pieces and pushed them into the “trash.” Neil noticed the buzz he created. He said of the science fair: “a whole bunch of people came over to my group and wanted to see bunch of things… They wanted to see the robot move.” Two scientists who acted as judges during the competition later told Jhumki that they felt his project was of a quality distinctly higher than those of any of his peers. Neil won first prize in the science fair competition, based on the evaluations of several ninth-grade judges. When he told Jhumki about his feelings about winning the prize, he said: “The day of the awards they [the students] were like, ‘Neil, Neil, Neil.’ I know it’s me. The students say ‘We all know it’s Neil getting awards.’ I was like, ‘Yeah it’s me, why not?”

Neil had profound interest in computers and robotics, fueled in part by his desire to invent new technologies to save the lives of soldiers in war. These interests, in many ways, propelled Neil into the role of capable physics student and expert. Not only were these changes reflected in his grades in the course but also in his developing identity as a capable school science expert. What is interesting is that despite the expertise Neil demonstrated in robotics and computing, he was not initially viewed by his peers or teacher as a good science student or an expert in physics. This is important because it suggests how easy it is to underestimate a student’s potential, based on his/her behavior in class, and how exploring a student’s interests and talents is an essential part of developing a young person’s critical agency.

Neil—a robotics teacher. A powerful aspect of Neil’s story is the way in which he cultivated and drew deeply upon his physics knowledge to position himself, over time, as an expert teacher who acted as a learning resource for his peers. Through physics, Neil altered how his peers viewed him, by presenting himself as a knowledgeable and serious student who could help them make connections between their lives and physics class.

During interviews for this study, Jhumki asked Neil to develop ideas for a lesson. Neil also chose to enact his ideas for teaching robotics with the whole class. He based his lesson on his experience with the robotics competition at a local university for which he had prepared and in which he enjoyed participating. He said of the
competition: “I met a lot of people at the tournament, teams that came over and helped us with programming. The people at the tournament, I liked them ‘cause they respected me.”

Over the course of the year during which this study was conducted, Neil spoke with his teacher several times about when and how he could build a game board, the kinds of equipment we could order for the in-school robotics competition he envisioned, and the kinds of funding we might acquire for materials. A year after Neil designed his unit, he and his team-mates had a chance to co-teach robotics with Jhumki as a unit of the “Medicine-Engineering” course offered to tenth-graders.

Jhumki chose the robotics kits the students would use, primarily based on the budget that the school allocated for the class. However, Neil and team-mates previewed the robotics kit before it arrived. Then they prepared the materials needed to run the robotics class: they unpacked equipment, figured out what types of batteries were needed, downloaded the software for programming onto ten laptops and sorted the Lego pieces for students to use.

Prior to each lesson, Jhumki would discuss with Neil and his team what they might do in class. The topics of the lesson mostly aligned with what Neil envisioned: constructing stable structures, exposing the students to various types of sensors, having its program and preparing students for an end-of-unit competition. In describing what he taught, Neil said:

The lesson was teaching students about robots because I did robotics. I liked it and I think all the students will. The first thing I be doing is introduce the topic, talk to the students about what robots means, what different things robots can do, what different parts of a robot are useful – touch sensor, light sensor – to start the robot. I tell them what it is used for. Then they write an evaluation – if Neil was a good teacher for the day or not. [I tell them] what different hydraulics can do, open and close, how to build claws.

In class, Neil moved between groups to help students solve building problems and become familiar with the software program. If during class, students struggled with programming or communication between the computer and robots, he came at lunch to try and sort out the problem, so next day’s class ran smoothly. Neil also helped collect and organize materials at the end of class. At one point, Neil recognized that all of the robotics team members were in one section of the medicine-engineering academy and none were in the second teacher’s classroom. Neil felt comfortable enough in his expertise to volunteer to be a student teacher in the other classroom, where he would not have access to Jhumki’s supervision. Neil designed the final game board for the competition on his own; in this sense, he created the parameters for the final assessment of the unit.

Neil’s interest in robotics and experience in physics allowed him to take on a new identity as a teacher in his classroom.

Neil—building social networks with peers and adults. Neil’s participation robotics afforded him more than knowledge of how to build and operate robots. This experience put him in contact with other students and adults who either shared this interest or wanted to see him succeed with it. Figure 2.4 depicts the strength of
Figure 2.4. Neil with team-mates and his father at the university robotics competition.

relationships Neil developed through robotics. The image captures the photographs from his university robotics competition that he considered important enough to gather together for presentation at the science fair. In the pictures, you can see that Neil has shown his team-mates working and posing together as well as a photograph of him with his father in which he describes his father as proud of him.

Building a strong social support network was important as Neil struggled with the transition to high school. He struggled with his grades and to cultivate positive relationships with his peers and teachers. The context of science provided Neil an opportunity to cultivate new relationships. Both the science fair and the co-teaching experience led Neil to expand his network of resources, including new adult relationships and new knowledge, upon which he could draw for doing robotics and computers. He regularly worked with and e-mailed two mentors at the local technical university sponsoring the robotics competition and found a summer internship at a robotics lab through materials he acquired from these mentors. He continued working with Jhumki over the next two years on his robot, setting and achieving goals for expanding his robotics skills until the 11th grade science fair. In 11th grade he even met with Jhumki’s husband and father, both of whom were computer programmers, to discuss programming his robot and to design business cards that captured his ability and desire to fix his classmates’ home computers.

Seeking out this adult help and mentoring reflected what was may have been a turning point for Neil. Despite Neil’s initial struggle with classroom behavior, he
began to find spaces through physics to build a network for success. He also began to project an identity as someone who was smart in this area rather than as someone who “acted dumb.” In physics class, Neil noticed the stature he could acquire by engaging in high-quality work: He said, “I do get respect sometimes when I do my work. Because when they pass me, they ask for help.” Neil also expressed his appreciation of the friendships he built through robotics.

The cohort of “friends” Neil made on the robotics team provided him with a social network that he maintained for the next three years. He organized a “going-away” party for one of his team members when this friend left for Trinidad at the end of Neil’s junior year. He also could be found meeting regularly with these friends and Jhumki, to discuss how to improve science teaching and learning for urban youth, even when Jhumki was not his teacher.

Agency and identity. Because engaging in agency involves reflection and the development of awareness, it necessitates that individuals continually examine their identities – who they are and how they change. Issues of identity – and how one positions oneself (or is positioned) through practice and identity building – are central to making sense of how one seeks to pursue one’s goals. In our use of the term identity, we align ourselves with those who view identity as fluid and constructed socially within communities of practice. Upon entering a community of practice such as the science classroom, students develop identities through engaging with the tasks of the science class. Learning science becomes “a process of coming to be, of forging identities in activity” or “identities-in-practice” (Lave & Wenger, 1991, p. 3). For example, how novice members of a community negotiate their relationships with the official authority, that is the science teacher or the recognized good science students, shape not only the goals students may choose to pursue but also how they identify with that community and its goals.

Bringing this framing of identity to bear on agency, we take the stance that the process of coming to be is rich with agentic possibility. As Holland (1998) argues, based on their particular “imaginings of self” (p. 5), individuals, as part of a process of agency, set particular goals towards which they want to direct their action. Evolving identities-in-practice can be inferred from the way students choose to interact with other members, the decisions they make with regards to the assigned tasks in the science classroom, the opinions and questions they raise and also their reticence and silence, should they choose not to participate. Holland (1998) writes of agency as a form of “semiotic mediation – modifying one’s environment with the aim, but not the certainty, of affecting behavior” (p. 39). Embedded within is the idea that pursuing agency does not guarantee a particular outcome but, instead, requires risk-taking, through which one might expend energy but not achieve one’s goal.

The relationship between Neil’s identity and agency. In physics, Neil leveraged the aspects of his identity that compelled him to pursue robotics such that he could build a new social identity for himself with respect to peers and adults. He expressed agency in that he used his experience in physics to change his life. Specifically, he positioned himself as a socially-connected expert and modified the world of his
school by instructing other students in robotics. Overall, Neil’s critical science agency was deeply connected to leveraging and expanding his identity. He drew on his passion for computers and robotics to develop as an expert, teacher and socially-networked young man.

Donya

Donya’s story in this study begins with her as a strong, motivated student interested in a career in law. During the student she explores challenging topics in physics such as black holes and dark matter and energy. She also tackles a unique, difficult science fair project. By the end of the study she positions herself as a scholar and expert who can guide her peers and as a young woman who challenges stereotypes about urban minority youth in science. She also says that she is more open to the possibility of a career in science.

Donya’s story suggests that the expression of critical science agency – expressing herself as powerful physics and scientific thinker in ways – was connected to her identity as a student and helped her expand her identity (such that she established herself as an expert student and scholar challenging what she saw as stereotypes about black students).

Donya—an expert student and scholar. Donya was a student who wanted to challenge herself. She applied these qualities in physics to expand her knowledge and scholarship, further developing her intellectual identity.

With regard to black holes, Donya began her investigation of this topic by intentionally choosing the most difficult of three topics for a first semester project on motion: how a moving object might avoid being drawn into a black hole. However, she did not feel that she had “learned everything” about black holes through her first semester project, so she decided to do more research on this topic in designing the lesson she chose to enact in Jhumki’s class. For her lesson, she studied topics as diverse as the density of white dwarves, the process of fusion, the formation of collapsed stars and the speed of light. Clearly, Donya sought out a depth of physics knowledge through the design of her lesson. Because Jhumki wanted students to learn about a topic other than black holes, since some of them had already encountered this idea for their first-semester motion project; Donya went a step further in her research by agreeing to conduct research on the topic of the lesson to dark matter and energy, a new topic for all students, instead of on black holes. She established a scholarly identity in this area by writing a paper on this subject, based on research, which provided the foundation for questions students should research for the debate. Donya also drew on her identity as a future lawyer to bring debate into her physics class.

By leveraging her desire for challenge and innovation, Donya also expanded her identity in the realm of scientific inquiry. She wanted to pursue an “original” project for the science fair, “something different” from what her peers were examining. She arrived at the idea of exploring how objects float, and she chose as her partner someone whom she thought would work hard, despite the fact that this student was
not her regular partner and best friend. She viewed this partner as “someone who will really commit to doing this project with me and really complete it.”

In agreement with how Donya said she normally sought out challenge, she described how she struggled with the number of hypotheses she was expected to generate for the science fair but enjoyed the new experience of conducting her own experiment. She said she liked “getting to check the results and test ideas in different ways.” During the science fair, Donya enjoyed being independent. She liked knowing where she was going with her work, to the extent that she could start work right away without waiting for her teacher’s instructions. She said, “In the three weeks, we knew what we were doing, we would just go to it.”

During the science fair, Donya and her friend displayed a detailed poster describing their experiments with floating different objects of different shapes and sizes in different types of liquids (oil, water, soda, etc.). They presented their findings on a detailed poster board documenting their scientific process. About the science fair, Donya said that she felt “really good, I felt we were doing something really extraordinary. It felt like we were in an art museum showing off our work.” She also took pride in a comment from a judge that described her project as “original,” different from the types of experiments other students had pursued.

Based on her experience with the science fair, Donya decided to further explore science. She said: “All in all, this experience has taught me a lot and I feel that I have started a new beginning because now I’m starting to think that I may like to pursue a field of science in college which is something I never thought I’d do.” The summer after her sophomore year, Donya enrolled in a nanotechnology course for high school students at a local university while also attending a pre-law program.

Donya—challenging stereotypes about black students. Donya relied upon this physics context to critically thwart the negative stereotypes that abound about black youth and the economic discrimination often seen in black communities. While Neil began to see a different future for himself through physics – one that allowed him to safely step out from “acting dumb,” Donya used physics to shield her aspirations from and challenge a racialized world. Donya’s involvement in physics demonstrated critical dimensions in that she explicitly challenged, through her actions as a science student, stereotypes about low-income, minority youth in science. As she states: “My name is Donya, I think the reason that most areas, black areas lack funding because...they think black people are just going to be the ones who work at McDonald’s, that’ why they don’t give us funding. They think it’s a waste of their money.” Through her decisions to challenge herself with the toughest science projects and as evidenced by her position on her school’s honor roll for every semester that Jhumki has known her – by leveraging her identity as a strong, capable student – Donya purposefully demonstrated that urban black students could be in a position to be excellent science students.

The relationship between Donya’s identity and agency. Donya expressed agency in that she changed her own life by positioning herself as a scholar and guide to other students and modified her world by creating a space in which students could
debate scientific ideas. Donya’s critical science agency was related to the development and expansion of her identity. Her commitment to challenge and innovation allowed her to expand her identity as a scholar, science inquirer and someone who challenged stereotypes about urban minority students.

Critical science agency and students envisioning their futures. Neil’s and Donya’s experiences with critical science agency indicate that this process was deeply connected with the leveraging and expansion of identity. In metalogues on this topic, Donya and Neil raised the point about identity but in a way that connected not only to who they are but who they want to be. This looking ahead on the part of students further emphasizes how taking action toward shaping identity is important to how these students frame their participation in science.

Donya: Science is more exciting to me and the whole class when the teacher structures a class around who the students are, or want to be.

Jhumki: Like wanting to be a lawyer.

Donya: Like being a lawyer. What is in science for me is that with the lawyer thing, there were a lot of topics that you could discuss that would be practice for being a lawyer. It’s not just how you might argue your point, even though that matters. It’s also about seeking out good evidence, and making it fit together to make a point. And it is also about asking hard questions that do not have obvious answers.

Angie: Donya and Neil, your stories about becoming a lawyer and a robot expert are telling me that part of what is important in helping you learn science is being open to how science intersects with not only who you are now but also your futures. In other words, developing a critical science agency is about developing an identity with and in science.

Neil: I think it is important for teachers to remember that students have goals that science can help us achieve, and that these goals are not always the same as getting a good test score. Sometimes these goals are really connected to the science we might learn. For the class I taught, it related to robots, which I want to do for Homeland Security. That class I taught also helped me how to understand how to program the robot, also open up my mind and set me on the correct path of what I want to achieve. But sometimes these goals are not really connected to the science directly. Like the science fair reflects on me, because I came in first place, and through the science fair, it shows what I can achieve. It helped me realize the goal that I want to achieve.

Donya: Learning science for me is about doing something. I mean its just not doing hands-on stuff because the debate is also doing something. I mean that learning science is also when you can do things that you develop yourself, like Nicolas said.

Jhumki: And so I need to see your learning, or at least part of your learning, in my class as about how you are able to build your future?
Neil: You know, it is not just how things directly tie to my future. I enjoyed learning about black holes even it wasn’t my topic. I learned a lot about black holes and I also learned about what Donya wants to be in the future. Why did she care about that? How did science class help her? If she wants to achieve in science to help her be a lawyer maybe that is something that I haven’t thought about. This is different than just learning what an atom is.

Critical Science Agency Involves the Strategic Deployment of Resources

Neil’s strategic deployment of resources. Neil’s initial interest in robotics was related to his concern for the well-being of American soldiers in Iraq. Throughout the year, he drew on resources inside and outside of school to expand his knowledge and experience and pursue his goals with respect to robotics. These experiences include his participation in an inter-school competition at a local technical university, choosing a robotics project for his science fair and participating in internships with the school computer expert and as a computer-use advisor to patrons at a local library.

Neil also drew on human resources to pursue his critical goals. For example, during the science fair, he came to school early, worked in Jhumki’s office at lunch and stayed late to build and program his robot. The week before the robotics competition, to improve his robot, Neil visited his mentors at the local technical university everyday after school for several hours. He relied on his peers as a resource in establishing himself as a robotics expert, relying on their help to co-teach his robotics unit with Jhumki.

We consider Neil’s deployment of resources to be strategic because he purposefully drew upon both traditional and non traditional resources in ways that positioned him with voice and authority, and in ways that challenged and even transformed normative and stereotypical rules for participation in science by urban youth. In our metalogues with Donya and Neil, Neil stresses how this strategic leveraging of resources is really a negotiation of who can participate and how that participation is made to matter to the larger community.

Neil: I think we have to include the other students in this negotiation, too. The kind of help I needed was a game board, which was a really big game board that my father built. And the robots competed against each other. And another help I needed was my friends gave me ideas, of where to put the different pieces on the game board – not this way but the other way, and they gave me feedback on where to put the different objects. I also got help from you on how to make the unit more organized so students know what they’re doing and would like it and could learn something from it even it wasn’t their topic. Cheef and Darius helped me because the programming was too hard to make the robot go forward, backwards, sideways. I needed help to make a claw, to put the pieces together to make a strong and powerful robot. They helped me a lot.
Jhumki: In addition to students, the larger context shapes this negotiation. Neil, do you think you would have been so involved in robotics if there hadn’t been that New York Robotics competition?

Neil: Yes, it was important. Because I met people and got to see what new people can do. Such thinking was very brainy, and I got to see it, the other students at the competition. The mentors they also gave you feedback, this part is right, this part is wrong, the program.

Angie: It seems to me then, that central to any negotiation – whether it be about identities, futures, content, or context – is a process of opening up and coming to know.

Donya’s strategic deployment of resources. Donya drew upon the context of physics to expand the repertoire of resources she could access and activate towards her own goals. We can see her goals coming into sharper focus as a result of her deployment of these resources. Donya’s expressions of and reflections on agency were dialectically related to context, rather than being limited to her own individualized experience. In her assessment of her dark matter/dark energy lesson, Donya suggested structuring debates based on her experience with the E=MC² debate and on classroom formats she had seen in end-of-year exit projects and during her visit to a local college. In choosing how to improve the debate the following year, she drew on the experiences and attitudes of her fellow students. In reflecting on her science fair, she drew on the comments of the scientists who had come to her school to judge her project. We consider Donya’s deployment of resources to be strategic because she purposefully drew upon both classroom and beyond-school resources in ways that positioned her as a scholar and expert and in ways that challenged traditional stereotypes about urban black youth in science.

Teacher as resource in critical science agency. Donya and Neil pointed out in their metalogue that they also significantly relied upon dialogue with their teacher as an important resource in this negotiation.

Neil: From my opinion, teachers should speak to the students and have their voices heard, have the kids say how they think class should be organized, how it should go along. Teachers should listen to what students have to say – students are the ones who are learning, not the teachers! As a teacher, you tried to help me achieve me my goals by having me, as a student, come and teach in the classroom. It helped me learn new things I never knew about and learn more ideas about how to help people.”

Donya: Jhumki, you gave me the idea of being the lawyer.

Jhumki: I did? I thought you were thinking of being a lawyer?

Donya: I mean, you helped me connect being a lawyer to black holes and to doing the debate. You helped me see how science class can help me achieve my goals.

Jhumki: So it sounds like our conversation one-on-one was helpful.
Donya: Well, I could not have done it on my own because what you told me to do was to make a list, write down what I needed to get this done. Having this in front of me made me see, yah, that is me. That is what I want to do. But then to think that black holes could help? I mean that is really true.

Jhumki: So you could lead class when I didn’t just tell you to lead class or I just decided to do class. It was that you had your ideas, and I knew some things, and we worked together. I could help you make a list.

Developing Critical Science Agency is an Iterative and Generative Process

We use the term *iterative* in this chapter to mean that a person constantly re-evaluates and modifies her knowledge and identity. By *generative* we mean that as a person expands his knowledge, his sphere of interaction, and his influence grow, allowing him to further access and activate new forms of capital.

Neil’s critical science agency as iterative and generative. Neil’s experience with critical science agency was iterative. He regularly wrote, tested and then modified programs to get his robot to perform in the ways that he desired. For example, Figure 6 shows his conclusions about how to make a robot turn, a conclusion he developed from a series of trial and error steps with robot motors. He taught his peers new ideas for building and programming, and had them test those ideas while he was there to help them.

Neil’s experience with critical science agency was also generative. His success with the science fair helped him develop his understanding of robotics while expanding his stature as a serious, smart student. His presentation on robotics during his end-of-year portfolio project established himself as a teacher of robotics. Both these experiences expanded his confidence and supported him in feeling excited and assured about teaching a full robotics unit to other students. These also inspired him to seek out internships in computer science and robotics outside the familiarity of his school setting, which in turn encouraged him to develop his robotics project further for the ninth-grade science fair. Over time, his behavior in physics class improved as did his willingness to rely on Jhumki in situations where he needed academic, personal or professional support, for example, seeking out Jhumki’s father in designing business cards or Jhumki’s husband for fixing his computer and developing a theory of programming.

Donya’s critical science agency as iterative and generative. Donya and Jhumki engaged in an iterative process when Donya developed her debate lesson. Jhumki asked Donya what kind of lesson she wanted to create; Donya discussed how she very much enjoyed the Einstein debate, in light of her interest in law, and said she wanted to pursue a debate. She chose a debate topic that appealed to her desire for challenge and originality, tapped on her experiences with her peers (particularly what she saw as their tendency to rely on one group member for completing work), and helped her fill gaps in her knowledge of black holes. Donya also suggested new
teaching practices that were very useful to Jhumki in designing debates by evaluating her experience with the debate she crafted. So, in Donya’s experience with critical science agency, Donya re-evaluated and modified both her knowledge and identity. She even expanded her career aspirations to include science.

Donya’s critical science agency was generative in that she developed new expertise about black holes, dark matter and dark energy. She also expanded her sphere of influence by working in a partnership with Jhumki, rather than simply being a recipient of the pedagogy Jhumki crafted. For example, Jhumki and Donya worked together to streamline the debate topic and traded rubrics, debate instructions and research questions for students back-and-forth, in designing the lesson. Eventually they debriefed about the success of the lesson, and Jhumki used Donya’s suggestions in her class the following year. Donya also established herself as a leader (teacher and judge) with respect to her peers, a social position that was important to her.

Donya’s and Neil’s metalogue reflections on how critical science agency was iterative and generative for them. We end this section on the generative and iterative nature of critical science agency with a brief metalogue with Donya and Neil because they summarize for us how learning to participate in physics and to use such participation to bring about change is transformative not only of their identities, but also of what it means to be successful in high school physics. Their actions changed their positioning in school science because they took on new roles and because we learned to respond to them in productive ways.

Neil: Well, what I know is that she did care, and my life is different now. I can be brainy and that is OK. I really don’t know how I would have been if Jhumki did not care. I would still be doing robotics, but it would not be in my physics class. Maybe I would still be skipping class.

Donya: At the beginning of ninth-grade, I didn’t like science, but I learned new things about science. Now, I’m even thinking of becoming a scientist. I’m a person who likes to be challenged, and I don’t like to know the answer right off the top of my head. I like to do research and have a scientific experience. Like with the debate. It gave me a different aspect of science. I didn’t know science had something that could go both ways. And I liked that part. But, it has changed me, and that matters for me both inside and outside the classroom.

Jhumki: And that change has taken place and makes sense in both of your worlds inside and outside the classroom.

Neil: And in the future. In ninth-grade, I did my first robotics competition and I went off to do it in class, and then I went off to doing an after-school program at New York College, and then I went off to doing a robot program at NY Technical School, making a robot that works underwater, and then I got second place at the eleventh-grade science fair. And I couldn’t do the programming, and I kept getting better and better. Like in my spare time, I would work on programming and then it would work, but back then I just got started. You know, I did not
try to become a better student on purpose. I acted dumb because it was part of me. But robotics has a purpose to me, and having that taken seriously gives me a place to be who I am and who I want to be. Being a good student is not following classroom rules. We shouldn’t talk about good students or even good teachers, but good science learning because that is how it happened for me.

CRITICAL SCIENCE AGENCY & DEMOCRATIC CLASSROOMS

In Donya’s and Neil’s stories we see two valuable points about critical science agency that both parallel and challenge each other. First, Donya used the context of physics to develop an identity as an expert physics student, who was both original and hardworking, whereas Neil used the context of physics to develop an identity more so as a specialized robotics expert and a teacher. Donya used her good social standing and school smarts, her hard work ethic, a sophisticated view of science, and confidence in taking risks to challenge stereotypical images of who can be successful and what it means to be successful in science. This differed from Neil, who drew more from adult networks, non-traditional knowledge, and a shared interest in robots to support his identity development.

Despite the difference in how their critical science agency played out in light of Donya’s and Neil’s different identities, our findings suggest that the expression of critical science agency for both youth was connected with their intellectual and social identities and the strategic deployment of resources. In addition, for both, the expression of critical science agency was an iterative and generative process. How these resources are either made available in classrooms or recognized and sanctioned by teachers is thus an important feature of empowering and democratic science education. Critical science agency supports youth in developing a kind of expertise that matters in their own lives – in how they build a sense of self and seek to interact in the worlds they traverse. Such situated expertise cannot necessarily be predicted before hand by a teacher. Thus, building opportunities for students to voice and act in such ways matters. This is not to suggest that teachers cannot lay claim to what their students ought to know. Indeed, critical science agency and subject knowledge are not at odds. In fact, an important aspect of expressing agency for both youth was the development of their physics knowledge in the context of their identity. Donya conducted research on a controversial topic in modern physics and applied it to her aspirations for a career in law and her quest for challenge and originality in her education. Neil became a robotics expert, and through this, established himself as a potential robotics developer and a scholar and teacher at his school. In their metalogue, Donya and Neil associated a positive physics experience with the development of knowledge. Donya felt that choice gave students the incentive and opportunity to better understand a topic. Neil felt that exposure to a robotics competition gave him “smart” ideas; this was a way to build his repertoire of robotics knowledge.

The iterative, generative nature of critical science agency is also an important feature to consider in building more empowering and democratic classrooms. In an
accountability climate, there is a sense of immediacy for urban minority youth to perform. For example, students and schools are often considering to be failing if test scores do not show a specific kind of progress. But the findings of this study suggest that the development of science expertise and engagement with science take time and ongoing human interactions. Neil became an expert by revising his work over time and building one opportunity in robotics upon another. Donya worked in conjunction with Jhumki to revise the plan for the following year. So the study suggests the need for longer-term metrics for understanding how low-income, minority youth learn science, with attention to their human interactions and the resources they leverage.

Key resources for the two youth in this study were in-class (physics curriculum such as the Einstein debate), out-of-class (end-of-year portfolio presentation), beyond-school (local university competitions and field trips), material (game board and robotics equipment) and human (teacher-student dialogue) resources. Donya and Neil, in their metadiscourse, also emphasized the importance of one-on-one teacher student dialogue in pursuing critical science agency. The findings suggest the importance of youth being exposed to a diverse world of opportunities that allowed them to create networks and mentoring connections in- and beyond-school.

Critical science agency, we believe, is an important construct in advancing our understanding of empowering and democratic science education. Clearly, the boundaries used to frame what it means to be literate in science are too narrow to fully grasp how both Neil and Donya grew as science scholars and youth who make a difference. The relationship between knowing and doing was not limited by traditional classroom activity, but was made more intense by the inclusion of out of classroom and out of school activity and an eye towards the future. If we had used traditional measures to make sense of either Donya or Neil, we would have a deficient view of their experiences in 9th grade physics. We may see Donya as a superior student – straight A’s in physics, good attendance and class participation. But Donya, in a sense, is at once more astute and fragile than her report card suggests. She worried deeply that her lesson plan failed, yet wanted her peers to know that science doesn’t always have answers. We may see Neil as a student on the verge of either passing or failing – skipping class, disruptive behavior intermingled with moments of success in the science fair. But Neil is much more cerebral and committed to his future than we might otherwise know. A framework of critical science agency, which requires us to understand that what students know is intertwined with who they are and want to be, has pushed us to develop more complex understanding of both youth.