SOCIAL JUSTICE PEDAGOGIES AND SCIENTIFIC KNOWLEDGE: REMAKING CITIZENSHIP IN THE NON-SCIENCE CLASSROOM

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ABSTRACT

This dissertation contributes to efforts to rethink the meanings of democracy, scientific literacy, and non-scientist citizenship in the United States. Beginning with questions that emerged from action research and exploring the socio-political forces that shape educational practices, it shows why non-science educators who teach for social justice must first recognize formal science education as a primary site of training for (future) non-scientist citizens and then prepare to intervene in the dominant model of scientifically literate citizenship offered by formal science education. This model of citizenship defines (and limits) appropriate behavior for non-scientist citizens as acquiescing to the authority of science and the state by actively demarcating science from non-science, experts from non-experts, and the rational from the irrational. To question scientific authority is to be scientifically illiterate. This vision of 'acquiescent democracy' seeks to end challenges to the authority of science and the state by ensuring that scientific knowledge is privileged in all personal and public decision-making practices, producing a situation in which it becomes natural for non-scientist citizens to enroll scientific knowledge to naturalize oppression within our schools and society. It suggests that feminist and equity-oriented science educators, by themselves, are unable or unwilling to challenge certain assumptions in the dominant model of scientifically literate citizenship. Therefore, it is the responsibility of non-science educators who teach for social justice to articulate oppositional models of non-scientist citizenship and democracy in their classrooms and to challenge the naturalized authority of scientific knowledge in all aspects of our lives. It demonstrates how research in the field of Science & Technology Studies can serve as one resource in our efforts to intervene in the dominant model of scientifically literate citizenship and to support a model of democracy that encourages the critical engagement of and opposition to scientific knowledge and the state.

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DEDICATION

For Sue Daniels
June 4, 1960-November 18, 2004

This dissertation is dedicated to my dear friend Sue Daniels, murdered and then burned to ashes in her home on November 18, 2004 by a man she had loved and who claimed to love her. My current understandings of and commitment to social justice and equity emerged in conversations with Sue and through working alongside her as an organizer in efforts to resist war and militarism; capitalism and globalization; oppression and marginalization based on differences in race, ethnicity, class, gender, sexual orientation, (dis)ability, nationality, and religion; and environmental destruction. At the time of Sue's murder, she was most passionately involved in efforts to promote justice and equity in Latin American (including work with the School of Americas Watch and the Colombia Support Network) and end mountain-range removal in southern Appalachia. As a biologist, Sue's research impacted the management and use of over a million acres of pine forest in the southeast region of the United States. I miss her passion, commitment, and enthusiasm, as well as her counsel and advice, no less today than any day previously – and this dissertation, and all other aspects of my life, are significantly poore for her loss. Sue and I were both scheduled to defend our dissertations at Virginia Tech this year. She will not have the opportunity to do so.

Sue wrote and read the poem below at a local *Take Back the Night* rally in March 2002. I include it here to reinsert her voice in the struggle to create a more just and equitable world and make visible her role in shaping the strengths (but not the weaknesses) of the dissertation that follows.

> They say, don't go there. That's a bad neighborhood. Stay Out.
> I say, go there.
>
> They say, you can't live there, that's a black neighborhood.
> I say, live there.
>
> They say, don't walk alone, don't go by yourself...
> I say, walk alone.
>
> They say, live in fear.
> I say, live.
>
> They say, stay at home, with your doors locked and your lights on, watching television.
> I say, Take Back the Night.

A year gone by and I am still broken.
Written for Sue Daniels on November 17, 2005

Tomorrow
it will be a year
since hope and strength were broken
Tomorrow I can no longer say (but)
"A year ago, I was so happy"
Tomorrow is a year of mourning
A year gone by and I am still broken.

How is a year measured?
How is a year marked?
A year of silence
A year of flinching
from eyes and words and arms
A year without
A year no longer able
to trust, to love, to speak, to act
A year in which I was not myself
not myself without her
A year ago, I was so happy
A year gone by and I am still broken.

Tomorrow
I must somehow learn
to trust, to love, to speak, to act
Tomorrow
I must somehow hold
your passion, beauty, hope, and strength
Tomorrow
is no longer time
for silence
for despair
Tomorrow, I promise, I rejoin the fight (but)
A year ago, I was so happy
A year gone by and I am still broken.

CHAPTER 1: INTRODUCTION

INTRODUCTION

After decades of sociological, philosophical, and historical analysis of the ways in which scientific knowledge production practices have been both shaped by and used to support systems of oppression and marginalization – including but not limited to inequalities based on intersecting differences of race, class, gender, sexual orientation, and dis/ability – why is it still *natural* for us to draw on scientific knowledge to create and maintain situations of blatant injustice? Where do we learn to interact with scientific knowledge in this way? And what tools are available to disrupt this process of *naturalization* of oppression within our schools and our society?

These questions emerged from my analysis of university and student discourses in response to an on-campus sexual assault as part of an action research approach to improving my teaching practices. Action research, also referred to as 'practitioner research' and 'teacher as researcher' (Stenhouse, 1975; Schon, 1983), is primarily about self-reflection on actions, followed by new action:

> Action research is a form of *collective* self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out. . . . The approach is only action research when it is *collaborative,* though it is important to realize that the action research of the group is achieved through the *critically examined action* of individual group members (Kemmis and MacTaggart, 1988, pp. 5-6).

As William Kyle has suggested, "Action research is part of a long tradition among grassroots activists to seek mutually constitutive relationships between research and social change. … Regardless of project focus, when viewed from a wider lens, all forms of action research are political" (Kyle, 1997, p. 669).

At 11 am on Monday March 31, 2003, a woman was sexually assaulted in a parking lot on the Virginia Tech campus – my campus since 1998. That day, in response to the reported sexual assault, the university issued a statement to the Virginia Tech community, "encourag[ing] prudence and vigilance on- and off-campus." Further, all recipients were instructed to, "When possible, walk with another individual and be aware of your surroundings. In addition, be mindful of campus emergency phones marked with blue lights." While this message was sent to the entire campus, the language it employed reflected a pattern of "blaming the victim" so common in sexual assault discourses, which seek to protect women from sexual assault by limiting their mobility, but in no way challenge the dominant discourses of masculinity and femininity that produce a "rape culture" on our university campuses, in K-12 educational contexts, and in our broader social environment.

Further, as feminist scholars have argued, this approach to dealing with sexual assault perpetuates the "rape myth" that a woman is too weak or helpless to challenge would-be assailants. This "rape myth" tells a woman that she must avoid all situations in which she could be attacked, thus severely limiting her basic freedom to move around in the world and making self-defense invisible as a valid response to the threat of rape and sexual assault. Finally, this type of response perpetuates the dangerous fallacy that rapists are unknown men and that rapes occur primarily in unknown or unusual places – whereas at least 80% of sexual assaults are committed by someone the victim knows and about 50% of sexual assaults occur in either the victim's or assailant's home. Most other assaults occur in public places like grocery store parking lots, libraries, jogging trails, and public laundry rooms – in other words, wherever women must be on a daily basis (McCaughey, 1997; Fisher, Cullen & Turner, 2000).

As an educator at Virginia Tech, I felt compelled to address what I saw as a dangerous and oppressive response by the Virginia Tech police to the reported sexual assault. On the following day, my Spring 2003 Social Foundations of Education class (a required course for undergraduate, non-science, pre-service teachers at Virginia Tech) was scheduled to begin a discussion of gender, gender roles, and sexism in U.S. educational contexts. The goals for the class, as a whole, included the examination of historical examples, different contemporary contexts, and ourselves as sites, to explore:

- our personal values and beliefs as they shape our teaching practices
- our personal identities and cultural histories of race, class, gender, and sexuality as these effect our teaching philosophies
- the popular myths and histories we have learned in our own schooling, families, and social experiences
- forms of truth and fiction portrayed by popular sources such as school textbooks and media (e.g. from popular culture to news and advertising) as these shape our values and beliefs (Boler, 2002).

At the beginning of this class, the day after the sexual assault, we mapped dominant discourses (or images) of masculinity and femininity in small groups and then together on the blackboard. These examples were drawn from the assigned readings and my students' everyday lives, as well as their teaching experiences: men are rational, women are emotional; men are strong and tough, women are weak; men are active, women are passive; and so forth. Our next activity was to explore what kind of interactions between men and women these social norms create. Some of my students noted how these dominant discourses of masculinity and femininity work together to provide what is necessary for a family to function well – paraphrasing the Victorian (white, middle-to-upper class) argument for the necessity of public and private spheres.

In the context of the recent on-campus sexual assault and the university's response to it, I decided to push the discussion in that direction and asked, "What other kinds of interaction do these dominant discourses of masculinity and femininity naturalize?" and then later directly asked the students to reflect on the sexual assault that had happened the previous day. In further discussion, some students began to suggest that the dominant discourses of masculinity and femininity make rape and other forms of sexual assault 'natural'. They continually recreate what I called the "rape culture" above – an everyday situation in which women must continually fear being attacked and one in which any man could rape any woman at any moment. At this point, I wanted to shift the discussion towards how we could then position ourselves as educators and community members to challenge these dominant discourses of masculinity and femininity and through this critique the university's response to the sexual assault. However, some of my students began to voice resistance and skepticism of anyone's ability to change the dominant discourses (or images) of masculinity and femininity. These students argued that our conceptions of masculinity and femininity are based on biological facts – not culture. That is, these students drew on sociobiologial and genetic research to argue for the biological determinism of masculinity and femininity and sexual assault: "If it's in our genes, we can't escape it."

Unfortunately, this science-based challenge to efforts to end sexual assault is not limited to my students, but is, instead, a nation-wide phenomenon. Recent academic and popular press publications by evolutionary psychologists, for instance, argue that rape is an evolutionary adaptation (Thornhill & Palmer, 2000; see Travis (2003) for a response). These discourses of "biological inevitably" have become part of the current socio-cultural context, and thus, within this context, it perhaps "made sense" that my students should call upon science-based arguments as a form of resistance to efforts to reshape society as we know it. That is, while I believe that many of my then students did wish to teach and act in ways that are not oppressive, they wished to do this in ways, as Kevin Kumashiro (2002, pp. 1-3) describes, that did not make visible their own complicity in systemic forms of oppression – like the current "rape culture" of the United States. Scientific discourses that "explain" why rape and sexual assault sometimes happen thus function as a resource that allows students (and others) to speak out against sexual assault and rape but to simultaneously continue to comfortably participate in dominant discourses of masculinity and femininity, knowing that they, themselves, are not to blame.

This dissertation is a product of my desire to grapple with the questions that emerged from my reflection on this 'critical incident' (Flanagan, 1954, 1982): Why is it natural to draw on scientific knowledge to create and maintain situations of blatant injustice? Where do we learn to interact with scientific knowledge in this way? And what tools are available to disrupt this process of naturalization of oppression within our schools and our society? This exploration is at once both private and public, in that I chose to explore these questions in such detail to both improve my ability to teach for social justice, and to initiate a broader discussion on the relationships between social justice, scientific knowledge, and non-scientist citizenship. Making this dissertation public is part of my ongoing action research process, and, in a sense, can be viewed as an opportunity for me to take action based on past self-reflection and to invite broader collaboration in both inquiry and changed practice. Whether or not the readers find my personal narratives truthful, I hope they will serve as 'points of entry' (Smith, 1987) for the broader discussion on social justice, scientific knowledge, and citizenship that I wish to promote.

DISSERTATION OVERVIEW

In trying to identify the tools that are available to challenge this use of scientific knowledge to create and maintain systems of oppression and marginalization, I came to realize that I needed to understand more about the ways in which my students, as non-scientists, had been educated (or trained) to interact with scientific knowledge. Further, I needed to understand how this training situated them to teach (or not to teach) and to act (or not to act) for social justice. That is, I needed to learn more about *where* non-scientists learn to interact with scientific knowledge and *what* relationships between scientific knowledge and non-scientists are naturalized within these contexts. I then needed to use this understanding of the ways in which non-scientist citizenship is connected to scientific knowledge to articulate an oppositional narrative that seeks to disrupt the use of scientific knowledge to create and maintain systems of oppression and marginalization.

I chose to focus my attention on the theory and practice of formal science education. While non-scientists receive cues as to how to interact with scientific knowledge from multiple authorities and at multiple locations outside of school (including the mass media, interactions with parents and peers, after-school clubs, museums and science centers, nature parks, and so forth), formal K-12 science education is a requirement for all students – and thus all future non-scientists – in the United States. Thus examining the ways in which formal K-12 science education articulates its vision for the science education of future non-scientists was a necessary part of my project.

While outsiders looking in towards the field of science education may assume that the primary purpose of science education is to train future scientists, training (future) non-scientists in the practice of a particular type of scientifically literate citizenship has competed for position as the primary goal of science education since the introduction of formal science education into the mandatory school curricula in the 19th century (Millar and Osborne, 1998; DeBoer 1991, 2000). In fact, the current national science education standards and reform documents in the United States (AAAS, 1989, 1993, 1997; NSTA, 1992; NRC, 1996) identify "science for all" as the primary goal of science education today.

There is nothing inherently wrong with the idea that science educators seek to train future citizens, not just future scientists. Within a world where non-scientist citizens are increasingly required to make private and public decisions about science and technology, this shift to include the needs of these future citizens within the science curriculum can be understood as "radical" (Osborne, 2004). However, the problem emerges, as I discuss in Chapter 2, in relation to the model of scientifically literate citizenship located within the standards, which has been shaped by the social, political, and economic contexts from which it emerged. In the 1980s, challenges to the authority of science and the state were identified as a growing internal threat to the nation. In governmental, popular press, and educational discourses, 'inappropriate' citizen behavior was redefined as scientific illiteracy. The science education reforms of the late 1980s and 1990s then responded to this threat by positioning the training of future non-scientists as scientifically literate citizens as the primary goal of science education. The model of scientifically literate citizenship located in the US national science education standards defines (and limits) appropriate behavior for non-scientist citizens as acquiescing to the authority of science and the state by actively demarcating science from non-science, experts from non-experts, and the rational from the irrational. This vision of acquiescent democracy seeks to end challenges to the authority of science and the state by ensuring that scientific knowledge is privileged in all personal and public decision-making practices.

This framework for the science education of (future) non-scientists – that is, scientific literacy for a specific type of citizenship – dominates the research and practice of formal science education today. This model of citizenship and of non-scientist interaction with scientific knowledge is why "science for all" must matter to educators committed to social justice. Michalinos Zembylas (2005) describes this as an 'egalitarian' perspective that "claims that all citizens have the right and the responsibility to become scientifically literate" (Zembylas, 2005, p. 710) so that they "will act as informed, responsible citizens when confronted with … [socioscientific] issues" (p. 711). Today, many proponents of this model of scientifically literate citizenship have adopted the language of 'deliberative democracy', 'public engagement with science', and/or 'dialogic teaching' (Alexander, 2004; House of Lords, 2000; US Congress, 2003; see also: Driver, Newton & Osborne, 2000; Millar and Osborne, 1998; Newton, Driver & Osborne, 1999; Osborne, 2002). However, the assumption remains, in this 'deliberative turn', that non-scientists must adopt the processes of scientific thinking to participate appropriately within personal and public decision-making contexts.

Understanding that my students have been trained in this manner helps to make sense of the role of scientific knowledge in my classroom and society at large. How have science educators committed to social justice intervened in the dominant model of scientifically literate citizenship and with what impact? Will these strategies work in the non-science classroom? Chapter 3 provides an overview of feminist and equity-oriented 'resistance' within the field of science education, and then evaluates the impact this resistance has had on the mainstream science education community and on the dominant model of "science literacy for citizenship." Angela Calabrese Barton (1998) identifies three different waves of feminist interventions within science education.

- First Wave Feminism in Science Education: Issues of Equity
- Second Wave Feminism in Science Education: Gender-Inclusive Science
- Third Wave Feminism in Science Education: Situating Knowing and Learning (Barton, 1998, pp. 1-19)

Each of the waves of feminist and equity-oriented interventions within science education focuses on making science more 'inclusive' for all – though the meaning and goal of 'inclusivity' is conceptualized differently depending upon the focus of the interventionist project. In each case, however, the focus is on increasing access to science by underrepresented and marginalized students. Michalinos Zembylas (2005) describes these feminist and equity-oriented interventions within science education as offering a "critical perspective" that seeks "to examine the power relations and inequities embedded in science education" and offer, as an alternative, "science teaching and learning practices that empower children, build solidarity, and initiate change—an emphasis on 'science education for social justice'" (Zembylas, 2005, p. 710).

These feminist and equity-oriented interventions within science education have had some success, in that they have created a space for research and practice focused on issues of equity and justice within the science education community and established a growing network of researchers and practitioners engaged in these projects. As well, the measured achievement of women and people of color within science education has improved, and more persons from underrepresented groups are choosing to pursue scientific careers.

However, while challenging the construction of scientifically literate citizenship has not been the primary goal of feminist and equity-oriented interventions, each of the waves offers conceptualizations of the non-scientist citizen, whether or not these are implicit or explicit. Do these new models offer good alternatives to the dominant model of scientifically literate citizenship? I argue that there are risks in the construction of non-scientist citizenship that each wave poses. For instance, the first wave implicitly categorizes students who do not pursue science education as 'failures'. The second wave's move to make scientific knowledge more inclusive by expanding what counts as science and scientific knowledge production practices suggests that experiences do not 'count' unless they can be called 'science' – perpetuating by extension the value-system of Western science. Finally, the third wave's re-theorization of non-scientists as citizens who can use and produce science as a tool for social justice by 'science as a tool for social justice' seems to paradoxically reify the dominant model of scientifically literate citizenship, in that "thinking like a scientist" is, again, the way to act. Can feminist and equity-oriented science educators challenge the dominant model of scientifically literate citizenship from within science education? At the conclusion to Chapter 3, I suggest that feminist and equity-oriented science educators may be unable to meet this challenge, at least by themselves, because of their participation in and constraint by hegemonic discourses and assumptions within the field.

The strategy of situating "science as a tool for social justice" is not limited to third wave feminist and equity-oriented interventions within science education. Instead, "science as a tool for social justice" is the dominant approach to arguing for civil rights for gay, lesbian, bisexual, transgender, and queer individuals in our country – employed by social justice-oriented educators both inside and outside science education to combat homophobia. Chapter 4 explores in more detail the risks in the model of non-scientist citizenship that "science as a tool for social justice" provides.

Within an often hostile and increasingly violent environment, the possibility of enrolling one of the most dominant forms of knowledge within our culture – science – to justify demands for equality for GLBTQ (gay, lesbian, bisexual, transgender, and queer) members of our communities and to make space to even talk about GLBTQ discrimination within educational settings is tempting, and at least initially appears to be a "win-win situation." This science-based discourse for equality is grounded, almost solely, on the argument that homosexuality is natural and unchangeable, and should be understood as "just another human variation" much like hair color or height. This use of scientific knowledge works as a strategic way to challenge religious fundamentalism, both within our classrooms and the larger world, and to resist legislative efforts aimed at further criminalizing homosexuality – particularly at a time in which our discourses of 'diversity', 'tolerance', and 'multiculturalism' seem to have failed or been appropriated.

However, certain dangers exist when we employ scientific knowledge to authorize our social justice work, particularly around issues of sexuality. This chapter seeks to push social justice educators to ask ourselves what we risk when we employ the "homosexuality and science" discourse – that is, "science as a tool for social justice" – to challenge the moral condemnation of homosexuality. One of the keenest dangers of adopting a science-based approached to GLBTQ rights to combat religious fundamentalism is that we participate in maintaining the "scientific fundamentalism" that currently competes for the domination of our culture. By "scientific fundamentalism," I mean the dominant model of scientifically literate citizenship identified in Chapter 2, in which science is assumed to be "an important force for human improvement, … offering a uniquely privileged view of the everyday world" (Irwin & Wynne, 1996, p. 6). Scientific fundamentalism argues that all personal and public decision-making processes should be guided by scientific knowledge. While, in this case, "we" become the "experts," this model offers a particularly constrained understanding of non-scientist citizenship – a model grounded in concepts of "neutral authority" and "value-free knowledge" that seems antithetical to basic tenets of social justice education. This approach limits our ability to use other forms of knowledge and alternative arguments for equality by participating in a discourse that legitimates science as the one true lens for understanding our world.

How, then, can the dominant model of scientifically literate citizenship be challenged – and by whom? This examination of dominant and existing oppositional models of non-scientist citizenship within Chapters 2-4 sets the stage for the primary conclusion to emerge from my engagement in this process of action research: *Social justice oriented non-science educators must offer resistance to the dominant model of scientifically literate citizenship through the construction of new oppositional narratives about the role and value of scientific knowledge in society.* We must take seriously our responsibility to disrupt the *naturalization* of oppression within our schools and society by critically engaging the authority of scientific knowledge in personal and public decision-making practices. Further, the non-science classroom can serve as a crucial site for this resistance. In Chapter 5, I provide a situated resolution to the problems and risks associated with the dominant model of scientifically literate citizenship by returning to two moments in my teaching practice: the critical incident described above, in which my students enrolled scientific knowledge to argue that rape is natural; and to my discussion of teaching in the midst of virulent homophobia that I provide in Chapter 4. Here, I suggest that research in the field of Science & Technology Studies can serve as a primary resource in the construction of new models of scientifically literate citizenship.

What is Science & Technology Studies (STS)? How can it serve as a resource? STS research over the past two decades provides alternative models of science and scientific knowledge production. What I am calling STS research includes work by scholars in cultural studies, ethnic studies, and women's studies, among other disciplines, that critically engages science, technology, and medicine, as well as work on these topics in anthropology, history, sociology, philosophy, and policy studies. By STS research, I mean more the critical interrogation of science, technology, and medicine rather than any specific institutional affiliation of the researcher. STS case studies produced from these different vantage points show that all sciences and technologies do have a politics, and thus provide a way of introducing an analysis of science into social justice pedagogies. In his introduction to the field, David Hess writes that STS provides:

> … a conceptual tool kit for thinking about technical expertise in more sophisticated ways. Science Studies tracks the history of disciplines, the dynamics of science as a social institution, and the philosophical basis of scientific knowledge. It teaches, for example, that there are ways of developing sound criteria for evaluating opposing theories and interpretations, but also that there are ways of finding the agendas sometimes hidden behind a rhetoric of objectivity. In the process, Science Studies makes it easier for laypeople to question the authority of experts and their claims. It

> teaches how to look for biases, and it holds out a vision of greater public participation in technical policy issues (Hess, 1997, p. 1).

Research in STS points to the special and unique role that science plays in Western culture today. Scientific knowledge, knowledge production practices, authority, and expertise function as ultimate truth in our society – science speaks *for* nature. Scientific knowledge can then be used to achieve closure in public and private debates, in most cases silencing alternative knowledge systems and knowledge producers – including non-Western indigenous knowledge systems.

Thus, through the lens of STS research, we can see that how we are trained to think about science – or not think about science – embodies different understandings of the status of its knowledge, knowledge production practices, authority, and expertise. These understandings then shape our ability (or lack of ability) to challenge science and form the context for the models of non-scientist citizenship in which we participate. STS research allows us to challenge the authority and legitimacy of scientific research, and the use of scientific research to support racist, sexist, classist, and homophobic agendas (c.f. Haraway 1988/1991, 1996; Harding, 1993). Thus, most importantly, STS research may create the opportunity to disrupt the model of acquiescent democracy that plays a dominant role in the conceptualization of the relationship between scientific literacy and non-scientist citizenship in formal science education. This ability is integral to the success of the social justice pedagogies and the creation of a more just and equitable world.

WHAT IS SOCIAL JUSTICE OR ANTI-OPPRESSIVE EDUCATION?

In this dissertation, I use the terms 'social justice' and 'anti-oppressive' education to describe the educational philosophy and pedagogical practice that I wish to support. Since I rely on these terms to such an extent in what follows, I would like to take this opportunity in the introduction to flesh out what I mean by these concepts. I recognize that much diversity exists amongst educators who "teach for social justice" or "teach for social change," however, social justice or anti-oppressive educators (whether from critical, feminist, anti-racist, multicultural, queer, anarchist or other perspectives) seem to agree, as Kevin Kumashiro (2002) writes, "that oppression is a dynamic in which certain ways of being (or having certain identifications) are privileged in a society while others are marginalized" (Kumashiro, 2002, p. 31). Disagreements amongst social justice or anti-oppressive educators exist "on the specific cause or nature of oppression, and on the curricula, pedagogies, and educational policies needed to bring about change" (Kumashiro, 2002, p. 31). One of the most important distinctions is whether educators understand oppression in individual or institutional/systemic terms. The ways in which educators understand oppression then shapes their choice of pedagogical goals and strategies.

Christine Sleeter (1996), for example, identifies five different types of social justice education: *Teaching the Culturally Different*: seeks to raise the performance of marginalized students by designing culturally compatible curricula; *Human Relations*: seeks to increase the sensitivity of all students ("We are all the same because we are different"); *Single Group Studies*, such as Women's Studies, Black Studies, Ethnic Studies; Queer Studies: seeks to provide students with the history of and contemporary challenges faced by the group under study to prepare them to challenge ongoing *Multicultural Education*: seeks to redesign schools (including curriculum, pedagogy, parent involvement, and tracking) to better model a more equal and pluralist society; and *Education that is Multicultural and Social Reconstructionist*: seeks to prepare students to resist political and economic oppression in all facets of society (Sleeter, 1996, pp. 6-7).

Kevin Kumashiro (2002) describes four different categories of social justice education: *Education for the Other*: seeks to improve the educational experiences of students who are marginalized or oppressed by mainstream society by focusing on individual prejudices, cultural differences, and interpersonal discriminatory treatment of these students; *Education about the Other*: seeks to add units, lessons, and topics about marginalized groups to the school curriculum to address incomplete and inaccurate knowledge, myths, and stereotypes; *Education that is Critical of Privileging and Othering* (Critical Pedagogy): seeks to critique structural processes of privileging and othering in order to challenge and transform structural oppression; and *Education that Changes Students and Society*: seeks to incorporate poststructural perspectives (i.e., identities are shifting and situated; knowledge is partial; and oppression is, in part, produced through discourse) to challenge the norm/Other binary and situate students to act to challenge oppression (while recognizing that the educator cannot proscribe what those actions should be) (Kumashiro, 2002, pp. 31-72).

Sleeter's and Kumashiro's analyses highlight many differences amongst educators who "teach for social justice" (and there are many other differences not described here). Some of the approaches adopt a liberal (or mainstream) approach to multiculturalism, and "take for granted that if individuals are taught to give up their individual prejudices and treat everyone the same, we will 'all get along', and any remaining limits to equal opportunity will simply disappear" and that "people are, with a few exceptions, rewarded on the basis of their merit" (Berlak and Moyenda, 2001, pp. 94). On the other hand, educators following critical (or anti-racist) multiculturalism emphasize the systemic and systematic nature of oppression and the ways in which "the entire social order is shaped by institutions that tend to preserve and reproduce prevailing racial, gender, and class inequities" (Berlak & Moyenda, 2001, pp. 92). In other words, "central to critical multiculturalism is naming and actively challenging racism and other forms of injustice, not simply recognizing and celebrating differences and reducing prejudice" (Berlak & Moyenda, 2001, p. 92). Critical multiculturalists understand education as a political project that can either perpetuate or challenge the systems of oppression in which it is embedded – that is, education can serve as both a disciplining (Foucault, 1975/1995) and/or liberatory (Freire, 1972; hooks, 1994) practice for students, teachers, and communities. Schools, from this perspective, are understood as institutions that are shaped by and transmit "ruling ideologies" (Althusser, 1971) and participate in the construction and maintenance of "hegemony" (Gramsci, 1971). Finally, critical multiculturalists argue that the goal of social justice education is not only to change students or schools but society.

From a critical multiculturalist perspective, then, I understand social justice education as seeking to create new practices of participation and social action – or citizenship – for students, teachers, and community members in order to challenge and change institutions and discourses to create a more just and equitable world. In no way are critical multiculturalists (or other educators who seek to challenge oppression that exists beyond inter-personal relationships) against working to decrease personal prejudices between students and teachers – what they/we are saying is that this strategy is not enough.

When I talk about "teaching for social justice" and describe the ways in which I organize my syllabi and class activities, I am often asked whether or not I think that I might better raise the questions I wish to ask by providing more "balance" in class materials. (I am also asked this question in regards to the ways in which I write for academic and non-academic audiences.) That is, my audience rightly imagines that one response to my practice of "teaching for social justice" is outright student resistance. This line of questioning enacts a number of myths, three of which I wish to address here. First, this line of questioning seems to assume that while my teaching practices are political, a more balanced approach would not be political. A second corollary assumption is that good teaching should not be political. A third assumption is that a balanced approach is the most effective strategy to encourage students to think critically.

In contrast to the assumption that "good teaching" is not political, social justice pedagogies recognize that teaching is a political act – how we educate and are educated shapes not only the ways with which we, and our students, interact with the world, but also the world, itself. From this position, choices in pedagogical approaches are read as value-laden and as embodying different understandings of knowledge, knowledge production, authority, and expertise. These understandings then enable or limit what knowledge, knowledge production practices, authority, and expertise can be contested or challenged by ourselves and our students, and what is off-limits (that is, what counts as 'natural' or 'normal', what is privileged, and what is not). Because teaching is a political project, it is never neutral and any perceived neutrality is a political achievement. For social justice educators, this neutrality is not an accurate representation of the position of the instructor, the politics of the curriculum, or the ideology embedded within specific educational models.

Critically, social justice pedagogies mean locating the politics of pedagogy in the space of real classrooms. Bob Peterson, a 5th grade teacher at La Escuela in Milwaukee, and editor of *Rethinking Schools*, writes: "Most teachers believe that politics should be kept out of the classroom. But it never is. Even a teacher who consciously attempts to be politically 'neutral' makes hundreds of political decisions – from the posters on the wall to attitudes toward holidays" (Peterson, 1994, p. 40). For Peterson, what a teacher *doesn't* do in the classroom is just as important as what the teacher does: What voices are silenced in the curriculum? What histories and practices are marginalized? Are controversies recognized or made invisible? Peterson argues that ignoring the political nature of education in the classroom and pretending to have no opinion on controversial subjects as a teacher "is not only unbelievable, but sends a message that it's OK to be opinionless and apathetic toward key social issues" (Peterson, 1994, p. 40). This encourages students to accept the knowledge, knowledge production practices, authority, and expertise of the dominant culture(s), thus limiting their ability to critically analyze and potentially disrupt or transform (or even consciously choose to support) the practices legitimized by the *status quo* narratives inside and outside of the classroom. Instead, what unites social justice approaches to education is an insistence on encouraging students to challenge the silences and omissions that Peterson (1994) identifies: "Whose voices? Which stories? What meanings? Who benefits? Why?"

Beyond implicit and explicit critiques of the myth of the neutral instructor, the type of "teaching for social justice" that I advocate simultaneously recognizes that teaching and learning can be (and should be, at times) dangerous and uncomfortable – for both the instructor and the students. Megan Boler (1999) describes this type of education as a 'pedagogy of discomfort', which aims to invite "educators and students to engage in critical inquiry regarding values and cherished beliefs, and to examine constructed self-images in relation to how one has learned to perceive others" (Boler, 1999, pp. 176-177; see also Kumashiro, 2002). Critically, social justice educators seeks to make visible taken-for-granted assumptions about the everyday world and to examine how our commitments – both emotional and political – "define how and what one chooses to see, and conversely, not to see" (Boler, 1999, p. 177). Students (and instructors) do often react to this project with what Boler calls "defensive anger" – which she sees as a very understandable "defense of one's investments in the values of the dominant culture" (Boler, 1999, p. 191). The question, then, becomes "How can I as an instructor respond productively to this (defensive) resistance?" Further: "How can I respond in a way that does not reinforce the idea that my political analysis is absolutely 'right' (and beyond critique) and other positions are absolutely 'wrong'?"

On the question of "balance" in educational contexts, I again turn to the work of Megan Boler (2001, 2004). Boler calls for what she describes as an "affirmative action pedagogy": "a pedagogy that ensures critical analysis within higher education classrooms of any expression of racism, homophobia, anti-Semitism, or sexism, for example. An affirmative action pedagogy seeks to ensure that we bear witness to marginalized voices in our classrooms, even at the minor cost of limiting dominant voices" (Boler, 2001, p. 321). Boler's argument for this type of pedagogy is based on the belief that "all voices are not free" in our current socio-cultural context – that is, some voices are marginalized within classrooms and the broader public sphere and some speech acts are more dangerous (or risky) than others. Thus, for Boler, the educational act of "silencing" dominant voices by critically analyzing "any statement made in a classroom, especially those which are rooted in dominant ideological values that subordinate on the basis of race, gender, class, or sexual orientation" (Boler, 2001, p. 321) may be 'discriminatory' but is not unjustified. For Boler, the classroom may be "one of the few places we may be able to exorcise some of the roots of inequality" because in this setting we can "consciously privilege … insurrectionary and dissenting voices, sometimes at the minor cost of silencing those voices which have been permitted dominant status for the past centuries" (Boler, 2001, p. 329). I understand most of my classes as a space to privilege marginalized perspectives as a "corrective" to the materials available in my students' other coursework and broader popular culture. Choosing to "balance" marginalized perspectives with the dominant or mainstream by allocating "equal time," on the other hand, may unwittingly continue to privilege the dominant perspectives with which my students are already well versed. (Note: While my students are not required to "adopt" the perspectives we examine in the course in order to meet the course criteria for success, they are expected to become familiar with these perspectives and to engage with the arguments and evidence presented – that is, to take the marginalized perspectives seriously.)

WHAT IS SOCIAL JUSTICE?

As an educator, researcher, and activist "committed to social justice," I have struggled to define what I mean by social justice in the context of what Kumashiro (2002) calls poststructural theory and what others have called postmodernity (Lyotard, 1984), late modernity (Giddens, 1998), or late capitalism (Jameson, 1991), amongst myriad other titles. That is, I take seriously the idea that all knowledge represents a partial perspective shaped by political, social, historic, cultural, and economic contexts – a perspective that makes the claim of universal knowledge impossible (i.e., the "god-trick" of infinite vision (Haraway, 1988/1991) and "a culture of no culture" (Traweek, 1988)). This situated knowledge raises questions about my and other's abilities to identify oppression and name it as wrong or unjust, because to do so we call on Enlightenment values such as justice, equality, liberty, democracy, etc. We also position ourselves as "knowing and seeing better" than others by privileging our own partial perspectives over theirs. This privileging, in fact, appears necessary to create social change. This conundrum has pushed me into political and ethical philosophy over the last year and seats me, as I write this, surrounded by books on theories of justice.

Feminist standpoint theorists and other feminist epistemologists, amongst others, have long struggled with this tension, but I have become increasingly dissatisfied with most of these answers as they seem to presume that someone (perhaps not me) can know what is unjust and what is more just and then act. In many cases, these new epistemologies rely on a shift from the individual to the community, and a shift in power and authority to currently marginalized groups. However, community values are not necessarily egalitarian or just, nor does once having been marginalized guarantee a political philosophy that seeks to end marginalization for all (that is, identity politics, while strategic, are not innocent nor 'the' solution). Finally, as an intellectual – as a white, mostly middle-class, mostly able-bodied, and mostly heterosexual university-based intellectual from the

United States – what should my role be in identifying and challenging injustice? The struggle, as Donna Haraway (1988/1991) long ago described it, is

> how to have *simultaneously* an account of radical historical contingency for all knowledge claims and knowing subjects, a critical practice for recognizing our own 'semiotic technologies' for making meanings, *and* a no-nonsense commitment to faithful accounts of a 'real' world, one that can be partially shared and friendly to earth-wide projects of finite freedom, adequate material abundance, modest meaning in suffering, and limited happiness. … Feminists don't need a doctrine of objectivity that promises transcendence, a story that loses track of its mediations just where someone might be held responsible for something, and unlimited instrumental power. We don't want a theory of innocent powers to represent the world, where language and bodies both fall into the bliss of organic symbiosis. We also don't want to theorize the world, much less act within it, in terms of Global Systems, but we do need an earth-wide network of connections, including the ability partially to translate knowledges among very different – and power-differentiated – communities. We need the power of modern critical theories of how meanings and bodies get made, not in order to deny meanings and bodies, but in order to live in meanings and bodies that have a chance for the future (Haraway, 1988/1991, p. 187).

The problem here, however, as above, is that without recourse to (some degree of) shared values and understandings of justice, equality, and so forth, Haraway's and my politics of solidarity and affinity require power (in one form or another) to act against the currently dominant institutions, disciplinary formations, and actors in our society.

What does this mean for a dissertation about social justice and education? For one, it means that this project is necessarily a work-in-progress. Tackling the question of "what is social justice?" is not my primary goal here. I recognize that this dissertation may not be useful in convincing educators and others who do not share my perspective on social justice education already to adopt it. Second, however, I am recently more and more intrigued with the arguments put forth by John Michael in his book *Anxious Intellects: Academic Professionals, Public Intellectuals, and Enlightenment Values* (2000). Michael seems to offer a compelling case for a "both/and" position in regards to what are typically understood as enlightenment values (though as Michael acknowledges, these values are not uniquely available in this tradition) and partial knowledges, arguing that,

> whenever we assert specific political positions, we rely on grand narratives to orient our polemics and to provide them with persuasive force. … [W]e must stop pretending that we have gotten beyond the vexed and conflicted Enlightenment traditions, the duplicitous and embattled grand narratives, that none of us on the Left has ever really been able to do without. We must stop distrusting the big words that make us so unhappy: justice, equality, solidarity, compassion, rationality, and all the rest. But we must also remember that these large abstractions will never resolve the arguments in which we engage. They are the terms in which those arguments must be conducted, the terms that those arguments themselves must specify. The simplicity of this answer in principle … does nothing to reduce the complexity of the problems that demand our attention. Without this answer, however, I do not see how we can make progress. We need to know not how to agree on these things (agreement not always being possible) but how to quarrel over them (Michael, 2000, pp. 16-17).

In making arguments and holding postions, Michael suggests that we can both draw on Enlightenment ideals of justice, equality, etc. at the same that we recognize that the meanings of these ideals are context-dependent (and historically-laden) and can (and should be) contested: "Justice, like other enlightened abstractions, does not resolve arguments; it is the name of the field on which battles are fought" (Michael, 2000, p. 55). In this sense, defining what I mean by "social justice" is without meaning unless I situate this definition within specific contexts. I would also suggest that my understandings of what is most socially just within different contexts (each with unique constraints and limitations) may not appear consistent, as this ongoing battle for meaning also takes places within me as a researcher, educators, and activist.

In terms of education and specific demarcations of the just and unjust, Michael suggests that, "one can base an effective pedagogy only on the belief that the version of reality that one advances in the classroom is accurate, that the arguments one uses to support one's position are good ones, that those who disagree are wrong according to specifiable criteria, and that their errors can be effectively demonstrated" (Michael, 2000, p. 54). In this sense, "Pedagogy always involves manipulation. A pedagogy that does not seek to transform its pupil is no pedagogy at all" (Michael, 2000, p. 53); "education without oppression and manipulation may not be possible. It may be that pedagogy must impose itself on its students in order, paradoxically or dialectically, to free them" (Michael, 2000, p. 51). While I support this acknowledgement of power (and manipulation) in the classroom, I am uncomfortable with Michael's description of pedagogy, in that it seems to disallow that the educator, herself, may also be transformed through the intersection of her and her students' pre-existing partial knowledges despite the power differential. Further, it makes invisible our responsibilities as educators to both argue and teach for what we believe is right and just and to *simultaneously* engage in an ongoing process of "critical inquiry regarding values and cherished beliefs" and an examination of "how our modes of seeing has been shaped specifically by the dominant culture of the historical moment" – what Megan Boler (1999, pp. 176-178), as noted above, describes as 'pedagogy of discomfort' for both students and educators (and others as a 'pedagogy of crisis' (Felman, 1995; Kumashiro, 2002)). Nonetheless, in this dissertation, I follow Michael's advice and re-embrace the words justice and equity and renew my hopes of understanding how to work to create a better, more just, and more equitable world.

ON METHODOLOGY AND EVIDENCE

In this dissertation, I move back and forth between 'personal' and 'professional' narrative, from teacher to researcher to activist, and I recognize that this movement to the personal and the political may raise questions about the meaning or validity of the research, as well as the generalizability and truthfulness of the conclusions presented. The sources of my analysis are also multiple and shifting, and range from government documents to past experiences as an educator, which are written in narrative form. This movement amongst 'voices' and 'data' reflects my attempts to navigate both the requirements of an academic dissertation and my motivations for pursuing this study, which were to reflect on and improve my teaching practice and initiate a broader discussion that may improve the teaching practices of other educators who "teach for social justice." However, this division between 'professional requirement' and 'improved pedagogy' is blurred for me, in that personal reflection requires rigorous understanding of the broader context in which I work, and the analysis of this broader context is motivated by a desire to become a better educator and serves as a site of situated knowledge production informed by my positioning and political projects. In effect, this continual movement is a challenge to the academic culture that seeks to separate reason from emotion.

At the same time, however, I recognize that I draw upon the tools of academic culture to make my arguments, for instance, for the role of emotion and other "non-scientific" forms of knowledge production in personal and public decision-making. While this is not the primary project undertaken here, my writing of this dissertation and ongoing discussions with colleagues, collaborators, and friends, have shown me why it is necessary to stake our claims on a broadening (or revolutionizing) of rationality and reason to include emotion, rather than a jettisoning of these concepts altogether, which was my original position. The social justice or anti-oppressive argument should be that emotion is a valid, justified, and (in some cases) required response to oppression and that this emotional response should count as a 'good reason' rather than be excluded as non- or a- or un-rational (Boler, 1999). In this way, what counts as a 'good reason' and what it means to be 'rational' becomes a site of conflict, a "field on which battles are fought" (Michael, 2000, p. 55).

The primary data that I draw on and the research methodology employed is determined by the specific research questions in each part of the dissertation. In Chapter 2, I ask: "How is the relationship between scientific literacy and citizenship conceptualized within the mainstream science education community and what are the political implications of this conceptualized relationship?" To answer this question, I examined the social, historical, political, and economic contexts of the recent US science education reforms that culminated in the enactment of US national science education standards in 1996. Primary data sources include: government documents; mass media news reports, editorials, letters to the editor, and commentary; the science education standards and reform documents produced by national science education organizations, including the American Association for the Advancement of Science, the National Science Teachers Association, and the National Science Foundations; articles, editorials, letters to the editor, and commentary in science education research publications; and other publications on the history and current practice of science education.

In Chapter 3, I ask: "How have feminist and other equity-oriented researchers within science education entered and transformed the mainstream science education community?" My primary data sources include: articles, editorials, letters to the editor, and commentary in science education research publications; other publications on the history and current practice of science education; the Social Science Citations Index and 2 interviews with the current and past chair of the Equity & Ethics committee of the National Association for Research in Science Teaching, who are both also active science education researchers on equity and social justice, as well as participant observation at international science education conferences. While not cited within the chapter, these interviews were used as a form of triangulation and verification of my analysis of the written artifacts of the science education community.

In addition to continued document analysis, Chapters 4 and 5 both include analysis of student discourses and my past experiences as an educator to situate my classroom as a site of action research. These analyses are written in narrative form. Other primary data sources include my class syllabi, student online postings and papers, as well as educational resources by other advocacy organizations and educational associations; mass media publications; and legal analyses.

Self-reflection about past experiences is a key aspect of action research, as discussed at the beginning of this chapter.

> The idea of self-reflection is central. In traditional forms of researcher researchers do research on other people. In action research researchers do research on themselves in company with other people, and those are doing the same. … Traditional researchers enquire into other people's lives and speak about other people as data. Action researchers enquire into their own lives and speak with other people as colleagues. Action research is an enquiry by the self into the self, undertaken in company with others acting as research participants and critical learning partners. Action research involves learning in and through action and reflection (McNiff & Whitehead 2000, p. 15).

Certain driving assumptions behind action research have been rightly criticized. For instance, Tom Brown and Liz Jones (2001) question the ways in which action research is linked to dominant conceptualizations of the Enlightenment project, and takes as 'given' the ability of researchers to both truly (and rationally) know what it is happening in their classrooms and then to understand needs to be changed to improve practices; the ways in which action research utilizes a mode of rationality that labels emotional responses as 'irrational'; the assumed stability of the identity of both researchers and researched (and the separation between them); and the linear and progressive narratives on which action research relies.

However, Brown and Jones (2001) argue for a reconceptualization of action research via a "lengthy engagement" with postmodernism. This engagement produces a change in action research, in which "the product of practitioner research does not result in statements of practical applications common to all" (Brown & Jones, 2001, p. 182). Rather, as Brown and Jones continue, this new mode of practitioner research would give:

> … an account of an individual practitioner examining specific issues within their practice and how these were addressed as problems within the research process. The practitioner, with their perspective and their way of working, is an essential part of the situation being described. In our account, the self, and the situation the self is in, are non-dualistic but, rather, are mutually formative, as part of each other. Further, the self/situation has an essential time dimensions understood by the individual through engagement in their situation. To understand the situation involves an appreciation of how the self/situation and the decisions faced evolve, and how this evolution might be seen in different ways (Brown & Jones, 2001, pp. 182-183).

Brown and Jones' reconstructive project for action research seems to run the danger of operating solely as a site of individual-centered reflection, and thus jettison the opportunity for the researcher to make arguments that seek to interrogate pedagogical theories and practices more broadly to create social change.

I want to say more than that. My "practice" of action research in this dissertation aims to navigate between their and others' critiques of the Enlightenment project, and a desire to (attempt to) create a more just and equitable world. I have drawn further inspiration in this navigation from theorists who employ personal narratives in research as a mode of autoethnography (Ellis & Bochner, 2003; Personal Narratives Group, 1989); personal experience narratives (Denzin, 1989);

critical autobiography (Church, 1995), self-ethnography (Van Maanen, 1995); or evocative narratives (Bochner, Ellis & Tillman-Healy, 1997, 1998). In this sense, my goal here is not to have produced a traditionally understood ethnographic account, but rather to see my experiences and the meanings I have attached to those experiences as data and the development of these accounts as research. Art Bochner describes the politics and process of evocative narratives in this manner:

> The word evocative contrasts the expressive and dialogic goals of this work with the more traditional orientations of mainstream, representational social science. Usually the author of an evocative narrative writes in the first person, making herself the object of research and thus breaching the conventional separation of researcher and subjects (Jackson, 1989); the story often focuses on a single case and thus breaches the traditional concerns of research from generalization across cases to generalization within a case (Geertz, 1973); the mode of storytelling is akin to the novel or biography and thus fractures the boundaries that normally separate social science from literature; the accessibility and readability of the text repositions the reader as a coparticipant in dialogue and thus rejects the orthodox view of the reader as a passive received of knowledge; the disclosure of hidden details of private life highlights emotional experiences and thus challenges the rational actor model of social performance; the narrative text refuses the impulse to abstract and explain, stressing the journey over the destination, and thus eclipses the scientific illusion of control and mastery; and the episodic portrayal of the ebb and flow of relationship experience dramatizes the motion of connected lives across the curve of time, and thus resists the standard practice of portraying social life and relationships as a snapshot ((Ellis & Bochner, 2003, pp. 217-218).

As Bochner continues, "Evocative stories activate subjectivity and compel emotional response. They long to be used rather than analyzed; to be told and retold rather than theorized and settled; to offer lessons for further conversations rather than undebatable conclusions; and to substitute the companionship of intimate detail for the loneliness of abstracted facts (Ellis & Bochner, 2003, p.

218). Like action research, the use of personal narratives invites continued discussion.

THOUGHTS ON AND FOR MY STS READERS

My dissertation is not only a conversation directed outwards from STS to social justice educators. Rather, it also serves as a pointed invitation for STS scholars to rethink the critical sites of STS research today and to explicitly explore the meanings of and goals for STS research in the new century. Today, the insights generated by laboratory and controversy studies occupy a space that is distinctly less radical than the spaces this research occupied in the academic and non-academic contexts of the 1970s and 1980s. What goals do we hold as we continue to produce further descriptions of the intersections of the social and the technical in ever more sites of scientific knowledge production and application? For whom do we research and write and why have we made these choices? What role does our research play in today's world and what role do we wish it to? For what reasons are we developing ever more complicated theories of the relationship between the technical and the social? To whom are we accountable?

These questions have achieved new prominence for me in the context of writing this dissertation to fulfill the degree requirements of my STS PhD. I have struggled in the writing of each part of this project to simultaneously produce something that "looks like" STS research at the same time as I seek to make this project meaningful for me, as well as (potentially) other social justice educators. Laurel Richardson (1991) argues that, "*How* we are expected to write affects *what* we can write about. … the *form* in which sociologists write theory shapes the *content*. (Richardson 1991, pp. 174-175). How do expectations for how we are expected to write in STS shape the content and arguments of our research? Richardson suggests that current expectations for academic writing in sociology perpetuate the dualities of "research/theory," theory/practice," "researcher/researched," and "sociological theory/self-theory" (Richardson, 1991, p. 177). However, Richardson calls for sociologists to challenge these dichotomies by "expanding the definition of who can do social theory" (everyone can, not just sociologists), "what social role sociologists can play" (teacher-facilitators, not philosopher-kings), and "how sociological theory should be written, or even if it needs to be written" at all (Richardson, 1991, p. 177).

In a later publication, Richardson suggests that we should think about writing as a "method of inquiry, a way of finding out about yourself and your topic" (Richardson, 1994, p. 516). As she continues, "Although we usually think about writing as a mode of 'telling' about the social world, writing is not just a mopping up activity at the end of a research project. Writing is also a way of 'knowing' – a method of discovery and analysis. By writing in different ways, we discover new aspects of our topic and our relationship to it. Form and content are inseparable" (Richardson, 1994, p. 516). Richardson argues that writing does not "reflect" social reality. Instead, it creates that reality: "Language is how social organization and power are defined and contested and the place where our sense of selves, our *subjectivity*, is constructed. Understanding language as competing discourses, competing ways of giving meaning and of organizing the world, makes language a site of exploration, struggle" (Richardson, 1994, p. 518). Thus, "what something means to individuals is dependent on the discourses available to them" (Richardson, 1994, p. 518).

These available discourses can also be thought of as "cultural scripts" which can be "cited" (Butler, 1997). I understand now that part of my struggle in writing this dissertation has been with my desire to resist citing dominant "cultural scripts" available to me that limit what counts as an "STS dissertation" – that is, the form to which an STS dissertation should conform – as well as what counts as "STS as academic research" more broadly.[1] The continued relevance of questions about the relationship between theory and interventions was brought home to me at this year's annual meeting of the Society for the Social Studies of Science (October 20-22, 2005). Here, a gap in research aim and location became visibly apparent, a gap that largely can be read as operating via generational divides – complicating the story I (and others such as David Hess (1997)) have told for years of feminist, critical, radical, and postcolonial STS research operating in opposition to "mainstream" STS research writ large. Instead, what counts as "mainstream" STS research appears to be shifting, at least for some members of the STS community.

"First-generation" STS scholars – those scholars who first established laboratories, controversies, and scientific knowledge production practices as sites of sociological analysis – continue to produce work in these programs, in a sense tinkering with established theories to make sense of changes in science over the last 30 years (e.g., Knorr-Cetina questioned whether 'black boxes' are sometimes now 'gray boxes' or 'transparent/clear boxes' or 'flat boxes' in the Presidential Plenary session). "Second-generation" and "third-generation" STS scholars, on the other hand, even those scholars who do not identify as feminist, critical, radical, or postcolonial STS researchers, appear to be broadly searching for new sites of STS intervention and new forms and goals of research practice.

"First-generation" STS scholars continue to tell the story of STS that highlights STS descriptive research as a critical and ongoing response to flawed normative programs in the

[1] More recently, I have been forced to realize how the writing I completed from June-September, 2005, shifted to cite dominant "cultural scripts" within science education, "conforming" to science education's standards of what counts as evidence and the ways in which this evidence and related arguments should be presented. This shift in writing practice occurred unconsciously, as I struggled "to pass" in my new position as a science education researcher in the Center for Informal Learning and Schools (CILS) at King's College London.

philosophy of science. "Second-generation" and "third-generation" STS scholars seek to re-engage in normative or reconstructive projects – for scientific and technical knowledge production, for science and technology policy, and for society – from a position that takes the sociological insights of STS research over the last 30 years seriously (as well as recognizing the ways in which current programs in the philosophy of science (and technology) have shifted to take into account these same or similar insights (e.g., Longino, 1990, 2005; Feenburg, 1999). This same shift in what counts as "mainstream" STS research was also visible at the STS (R)evolutions conference that Virginia Tech graduate students organized in Spring '05. Of course, the distinctions I have drawn between "first-generation" and later generations STS scholars do not hold true in all cases. There have always been activist strands of STS research, and many "first-generation" STS scholars were motivated to enter the field because of these motivations (e.g., feminist, anti-racist, anti-nuclear, and "science for the public good" movements), while other "first-generation" scholars are shifting to more normative projects. Further, as indicated above, I am now willing to grant that "first-generation" STS research was once radical. However, it no longer is.

Gary Downey (2001) identifies doubled goals for the field of Science & Technology Studies. On the one hand, STS scholars seek to provide a more complex narrative about the intersection of science, technology, and society. On the other hand, STS scholars seek to use these insights to create spaces for intervention and choice within today's technoscience world. Downey sees the anthropology of science as providing one way to mediate between these two agendas, which, while compatible, often are realized in separate projects within the social and cultural studies of science and technology, with the first project receiving significantly more attention than the latter. Addressing this tension is critical to my own work as a scholar and activist, and to "my generation" of STS scholars. Thus, to the STS audience of this dissertation, I wish to make two related arguments. First, to "first-generation" STS scholars (and those who operate in their footsteps) – it is time to rethink the critical sites of STS research today and to explicitly explore the meanings of and goals for STS research in the new century. Second, to STS scholars already engaged in this reflexive process – science and non-science education theory and practice is a valid and necessary site for our normative or interventionist projects.

Feminist STS scholars have long directed attention to examining formal science education. As is the case for feminist and equity-oriented work within science education, much attention by feminist STS scholars has been directed towards exploring why there are so few women and people of color at all levels of STEM education, and how structural, pedagogical, and content changes can address these gaps (c.f. Etzkowitz et al, 2000; Rosser 1988, 1990, 1995). A second strand of work has focused on the development of a more socially responsible science and scientists (c.f. Schiebinger, 2001; Lederman & Bartsch, 2001). However, little attention has been directed by these scholars, on the other hand, toward the science education of non-scientists, and the ways in which formal science education normalizes a problematic model of scientifically literate citizenship. As well, again based on my observations at this year's Society for the Social Studies of Science conference, science education (whether for future scientists or non-scientists) is too often ignored, even by members of "my generation."

The education of future scientists and non-scientists is a logical site for normative projects in STS as we try to intervene in scientific and technical knowledge production, science and technology policy, and society. What are the multiple roles that STS research can play as a both a tool and mode of analysis for pedagogical projects that seek to create change? My dissertation provides one example of the type of work that STS can do in theorizing social justice pedagogies and analyzing curricular content and educational policies, and highlights the need for STS to examine the formal education of both future scientists and non-scientists in science and non-science classrooms. I see research programs developed within STS as always already teaching materials – it is time that we, as a field, engaged more seriously in this pedagogical opportunity and responsibility.

CHAPTER 2: THE LIMITS OF APPROPRIATE BEHAVIOR: SCIENTIFICALLY LITERATE CITIZENSHIP IN THE US NATIONAL SCIENCE EDUCATION STANDARDS

INTRODUCTION

What is the purpose of science education? For outsiders looking in towards the field of science education, it seems obvious that the primary purpose of science education is to train future scientists. However, within the field of science education, training (future) non-scientists in the practice of a particular type of scientifically literate citizenship has competed for position as the primary goal of science education since the introduction of formal science education into the mandatory school curricula in the 19th century (Millar and Osborne, 1998; DeBoer 1991, 2000). While the term scientific literacy was first used in 1958 (Hurd, 1958; McCurdy, 1958; Rockefeller Brothers Fund, 1958), science educator Rodger Bybee argues that, "The idea of scientific literacy has been a key factor in the formation of school science programs throughout our history. … The term has been increasingly used as a shorthand version of the fundamental goal of science education" (Bybee, 1997, p. 46). The current national science education standards and reform documents in the United States (AAAS, 1989, 1993, 1997; NSTA, 1992; NRC 1996) identify "science for all" as the primary goal of science education today. Why is training (future) non-scientists so important to science educators? What are the connections between scientific literacy and citizenship? How does the citizenship training provided by science education position students to challenge injustice and create a more equitable world?

To answer these questions, it is important to understand that what counts as the dominant goals of education are shaped by the socio-political contexts in which the guiding educational policies and practices are developed. Educators and policymakers respond to perceived threats to the nation by reconstructing the primary purposes of education so as to minimize these threats and stabilize the social order. Over the last century, science education has served as a key site for these efforts. Historian of science education George DeBoer (1991, 2000) has identified nine different, competing goals for teaching science over the last 150 years: 1) teaching and learning about science as a cultural force in the modern world; 2) preparation for the world of work; 3) teaching and learning about science that has direct application to everyday living; 4) teaching students to be informed citizens; 5) learning about science as a particular way of examining the natural world; 6) understanding reports and discussions of science that appear in popular media; 7) learning about science for its aesthetic appeal; 8) preparing citizens who are sympathetic to science; and 9) understanding the nature and importance of technology and the relationship between technology and science (DeBoer, 2000, pp. 591-593; see also Jenkins, 1997; Norris & Phillips, 2003).

Shifts between goals occurred in response to the identification of new internal and external threats to the nation. For instance, the primary purpose of science education during the Progressive era (1920s) was to teach recent immigrant and lower class students "life skills" to minimize the perceived internal threat of divergence from white, middle-class norms (DeBoer, 1991; see also Layton (1973) for a discussion of similar efforts in Britain). In the 1950s and 1960s, the primary purpose of science education shifted to the production of future scientists to meet the perceived external threat posed by the Soviet Union during the Cold War (DeBoer, 1991; however, see Rudolph (2002) for a discussion of how post-World War II science education reforms were simultaneously motivated by the identification of a scientifically illiterate public as an internal threat to the autonomy of science and scientists).

The current US national science education standards were developed in the 1980s and 1990s, a time period marked by significant changes in the national identity of the country and the identification of new internal and external threats to the nation. Significant attention has been directed towards analyzing the ways in which the identification of a new external threat reshaped the purposes of science education. International struggle, understood to be a question of political and military might during the Cold War, was redefined on a new battleground of global economic competitiveness, as “States were forced to re-imagine themselves without clear-cut enemies’ in a globalizing world” (Elam & Bertillson, 2003, p. 239; see also: Elam, 1997; Giddens, 1998).

> The power of patriotic commitment to this economic call to arms becomes concentrated in the slogan of competitiveness and its logic of productivity, which locates humans alongside technology and capital as resources for the production of consumer goods. Popular theorizing about competitiveness seems to reach into everyday lives and selves much more than the military logic of the Cold War did, because it turns every action into an economic defense of the nation. Something is good if it enhances competitiveness and bad if it does not (Downey and Lucena, 1997, p. 121)

This “doctrine of competitiveness” emerged at a time in which “America was [seen as] threatened by economic defeat at the hands of international competitors, particularly Japan” (Downey, 1998, p. 7). According to Juan Lucena (2005), the primary purpose of science education was reconfigured in response to the identification of this new external threat to the nation in the 1980s. Economic competitiveness was linked to technological innovation, and the government, popular press, and science educators responded by positioning the production of engineers as the primary goal of science education as the solution to the external threat to the United States. The goal of training future basic scientists, a hallmark of Sputnik-era educational reforms, was replaced by the goal of increasing the number of engineers and applied scientists, leading to the dominance of the science and engineering pipeline metaphor.

However, little analytical attention (outside the field of science education) has been directed towards the ways in which the current national science education standards are, in fact, more about training future (non-scientist) citizens than preparing future scientists or engineers. How can this be explained if science education is understood to be a site of response to perceived threats to the nation? To answer this question, it is necessary to turn our attention to the identification of new internal threats to the nation. The 1980s were also a time period marked by a backlash against social and political movements that questioned the authority of both science and the state in the 1960s and 1970s. These movements included the civil rights, anti-war, women's rights, black power, and gay and lesbian liberation movements, which challenged the authority of the federal and state governments, and the medical, psychiatric, media, and educational professions, among others. The anti-nuclear, science for the public good, appropriate technology, and environmental movements of the 1960s and 1970s also provided direct challenges to governmental policies and the goals and practices of science and engineering. These conflicts explicitly disrupted the appearance of a unified US culture and national political consensus.

This questioning of authority challenged the internal stability of the nation and was part of the emerging 'risk society', a period of increasing production and awareness of risk and decreasing trust of expert knowledge (Giddens, 1990; Beck, 1992). New awareness of risks included the:

1. *Globalisation of risk* in the sense of *intensity*: for example, nuclear war can threaten the survival of humanity;
2. *Globalisation of risk* in the sense of the *expanding number of contingent events* which affect everyone or at least large numbers of people on the planet: for example, changes in the global division of labour;
3. Risk stemming from the *created environment*, or *socialised nature*: the infusion of human knowledge into the material environment;
4. The development of *institutionalized risk environments* affecting the life-chances of millions: for example, investment markets;

5. *Awareness of risk as risk*: the "knowledge gaps" in risks cannot be converted into "certainties" by religious or magical knowledge;
6. The *well-distributed awareness of risk*: many of the dangers we face collectively are known to wide publics;
7. *Awareness of the limitations of expertise*: no expert system can be wholly expert in terms of the consequences of the adoption of expert principles (Giddens, 1990, pp. 124-125).

The emergence of a 'risk society' disrupted longstanding divisions between haves and have-nots, in that the negative consequences of scientific and technical innovation and state policies are no longer limited to the poor or otherwise marginalized groups (though these groups are often still inequitably exposed). Instead, all persons – even those with substantial resources – are at risk.

In the 1980s, challenges to the authority of science and the state were identified as a growing internal threat to the nation. Science education was reconfigured to address this threat by defining "science for all" as its primary goal. Today's national science education standards offer a model of scientifically literate citizenship that seeks to curtail the 'risk society' of the 1980s – and the attendant challenges to the authority of science and the state – by training future citizens to think like scientists, thereby positioning them to participate more appropriately in civic society. In this chapter, I show how scientific illiteracy was defined as an internal threat to the nation in the 1980s in governmental, popular press, and educational discourses. The science education reforms of the late 1980s and 1990s then responded to this threat by positioning the training of future non-scientists as scientifically literate citizens as the primary goal of science education.

Previous analyses of efforts to increase adult public understanding of science have described the ways in which these educational efforts rely on an assumption of public ignorance, in which the general public is understood to lack "a basic understanding of scientific facts, theories and methodologies" and public controversies are understood to be "created by inadequate public understandings rather than the operation of science itself" (Irwin & Wynne, 1996, p. 6). My analysis is informed by this work, primarily located in the United Kingdom. While each of these previous case studies (e.g. citations) focused on "context-specific and local analysis of 'public understanding of science,'" common analytical questions include:

- What do [lay] people mean by 'science' and 'scientific expertise'?
- Where do they turn for technical information and advice?
- What motivates them to so?
- How do they select from, evaluate and use scientific information?
- How do they relate this expert advice to everyday experience and other forms of knowledge? What is involved in its integration at this level? (Irwin & Wynne, 1996, p. 11).

Insights from this research have made visible the complex relationship between citizens, scientific and technical knowledge, and science education. As Sheila Jasanoff (2005) argues, "These far-flung activities [public understanding of science] say less about how publics know things in contemporary societies than they do about the presumptions underlying scientists' (and secondarily the state's) expectations of what publics should know. … … Together, these elements of PUS can be seen in effect as a kind of tacit democratic theory – a theory that presumes ignorant publics are in need of rescue by the state and grants science a privileged place in forming, and informing, an educated citizenry" (Jasanoff, 2005, p. 252).

What kind of tacit democratic theory informs US formal science education efforts directed at the education of (future) non-scientist citizens? The analysis in this chapter suggests that the US model of appropriate scientifically literate citizenship shares some of the features of the deficit or public ignorance model of science education, but differs in other, important ways. In both cases, it is the non-scientists that must be 'fixed', not science or the policy-making process or the values that underlie both science and policy. However, whereas the deficit model in the UK 'fixes' scientific illiteracy by filling non-scientists with basic facts about science (a banking model of education), the dominant model of training in the US context is process-based. In this model, future non-scientist citizens have to be trained to "think like scientists," so that they may think rationally and use quantitative risk assessment in their personal and public decision-making processes. They must develop "scientific habits of mind" and adopt the "scientific worldview" through exposure to the history and the nature of science so that they can actively participate in demarcating between science and non-science, experts and non-experts, rationality and irrationality, and so forth.

This process-orientation has been called the "second phase of PUS" in the UK. However, in the US, a focus on scientific process has been intertwined with the tacit (and sometimes explicit) democratic theory informing formal science education since at least the early 1980s. The model of scientifically literate citizenship offered by the US science education reforms is based on a theory of acquiescent democracy, in which non-scientists citizens must actively acquiesce to the authority of science and scientists in personal and public decision-making practices, thereby ending challenges to the authority of science and the state. In this chapter, I show how this turn towards "science for all" within formal science education was a response to the construction of scientific illiteracy as a threat to civic society in the 1980s, and explore the limits of the model of citizenship embedded within today's formal science education practices.

DEFINING SCIENTIFIC ILLITERACY AS A THREAT TO THE NATION

In the 1980s, scientific illiteracy emerged as an internal threat to the United States. In national reports on the state of education, mass media publications, and science education literature, scientifically illiterate citizens were portrayed as a threat to democracy and civic society because of poor or inappropriate public and private decision-making practices that questioned the authority of science and the state. In this section, I tell the story of the emergence of scientific illiteracy as a threat to the nation. This renewed attention to scientific literacy followed the pattern of a moral panic, in which scientific illiteracy became defined as a threat to the social order. Moral panic – as a category of analysis – emerged from work at the Birmingham Centre for Contemporary Cultural Studies in the 1970s in connection with analyses of youth culture. Stanley Cohen, in his book *Folk Devils and Moral Panics: The Creation of the Mods and the Rockers* (1972), wrote:

> Societies appear to be subject, every now and then, to periods of moral panic. A condition, episode, person or group of persons emerges to become defined as a threat to societal values and interests; its nature is presented in a stylised and stereotypical fashion by the mass media; the moral barricades are manned by editors, bishops, politicians and other right-thinking people; socially accredited experts pronounce their diagnoses and solutions; ways of coping are evolved or (more often) resorted to; the condition then disappears, submerges or deteriorates... Sometimes the object of the panic is quite novel and at other times it is something which has been in existence long enough, but suddenly appears in the limelight. Sometimes the panic passes over and is forgotten, except in folklore and collective memory; at other times it has more serious and long-lasting repercussions and might produce such changes as those in legal and social policy or even in the way the society conceives itself (Cohen, 1972, p. 9).

Kenneth Thompson (1998) summarizes the five key elements or stages in a moral panic as:

1. Something or someone is defined as a threat to values or interests.
2. This threat is depicted in an easily recognizable form by the media.
3. There is a rapid build-up of public concern.
4. There is a response from authorities or opinion-makers.
5. The panic recedes or results in social changes (Thompson, 1998, p. 8).

Implicit, as Thompson points out, in the concept of moral panic is "the suggestion that the threat is to something held sacred by or fundamental to society. The reason for calling it a *moral* panic is precisely to indicate that the perceived threat is … a threat to the social order itself or an idealized ('ideological') conception of some part of it" (Thompson, 1998, pp. 9-10).

This section of the chapter maps the emergence and escalation of the moral panic about scientific literacy throughout the 1980s. This discussion of the stages of the moral panic provides an historically-informed lens through which to revisit the new national science education standards and reform documents and contextualizes the current emphasis on "science for all" as the primary purpose of science education today.

Defining Scientific Illiteracy as a Threat to Values or Interests

In the early 1980s, scientific illiteracy was first identified as a threat to the social order via the publication of reports on the state of education in the United States by numerous governmental and non-governmental bodies. These reports include: *A Nation at Risk: The Imperative for Educational Reform* (1983), by the National Commission on Excellence in Education; *Action for Excellence* (1983), by the Task Force on Education for Economic Growth; and *Educating Americans for the 21st Century* (1983), by the National Science Board Commission on Precollege Education in Mathematics, Science and Technology.[1] In these reports, the problem of scientific illiteracy amongst the school-age and adult populations was recursively positioned as a major threat to internal stability of the state and to its external dominance in the new post-Cold War era – that is, scientific illiteracy was described as creating risks in economic, civic, and military arenas. The groups responsible for these reports were comprised primarily of national and state officials, business leaders, and educators. They were a response to the "the widespread public perception that something is seriously remiss in

[1] In this chapter, references from these reports use the following notation in parenthetical citations: **ANAR** refers to *A Nation at Risk: The Imperative for Educational Reform* (1983), by the National Commission on Excellence in Education; **AFE** refers to *Action for Excellence* (1983), by the Task Force on Education for Economic Growth; and **EA21C** refers to *Educating Americans for the 21st Century* (1983), by the National Science Board Commission on Precollege Education in Mathematics, Science and Technology.

our educational system" (ANAR, 1983, np) and were "emblematic of the period, one of great concern about the economic well-being of the United States and an enthusiasm to do something to improve education" (Collins, 1998, p. 25).

The solution, as articulated in these reports, is increased accountability, increased testing, and the redefinition of scientific and technical literacies as the "new basics" for all students – "the *thinking* tools that allow us to understand the technological world around us" (EA21C, 1998, p. v). Many previous analyses of these reports and the new environment of risk have focused on the descriptions of the economic threat and the need for the US to remake itself and its workforce in order to remain internationally competitive. Predominantly, these analyses have focused on the ways the reports provide the incentive for the remaking of professional education for scientists and engineers during this time period. However, this type of analysis misses two key features of the reports that I will highlight here. First, the reports are about the education of *all* students, not just future science, technology, engineering, or mathematics (STEM) professionals. Second, much of the risk of an uneducated population is to the social order – in addition to US economic and military pre-eminence.

First, according to these reports, deficits in education must be addressed for all children, not only future scientists and engineers, so that "all children by virtue of their own efforts, competently guided, can hope to attain the mature and informed judgment needed to secure gainful employment, and to manage their own lives, thereby serving not only their own interests but also the progress of society itself" (ANAR, 1983, np). This improved education will contribute not only to an increased STEM workforce and a more competitive U.S. economy, but will form "the foundation for a satisfying life, an enlightened and civil society, a strong economy, and a secure Nation" (ANAR, 1993, np). The nation must:

> demand the best effort and performance from all students, whether they are gifted or less gifted, affluent of disadvantaged, whether destined for college, the farm, or industry … based on the beliefs that everyone can learn, that is everyone is born with the urge to learn which can be nurtured, that a solid high school education is within the reach of virtually all, and that life-long learning will equip people with the skills required for new careers and for citizenship. (ANAR, 1983, np)

Educating Americans for the 21st Century likewise focuses on the education of all students, not just potential scientists and engineers. The plan of action proposed in the report aims to "enrich the [mathematics, science and technology] educational experiences of the entire range of American students – those planning careers as professional mathematicians, scientists, engineers and teachers in these fields, those who will pursue technical careers, and those who will be the Nation's future political leaders, managers, laborers, parents, consumers and voters" (EA21C, 1983, np).

Second, as described in the reports, the threat to the nation is three-fold: economic, military, and *civic*. The risks of an uneducated population, according to these reports, are simultaneously to "our national defense, our social stability and well-being and our national prosperity" (AFE, 1983, p. 14); to "the intellectual, moral, and spiritual strengths ... which knit together the very fabric of our society" (ANAR, 1983, np); and to "the maintenance and development of our Nation's economic strength, to its military security, to its continued commitment to the democratic ideal of an informed and participating citizenry and to fulfilling personal lives for people" (EA21C, 1983, p. 1). According to the reports, scientific illiteracy limits the ability of individuals "to participate fully in our national life" (ANAR, 1983, np) because,

> A high level of shared education is essential to a free, democratic society and to the fostering of a common culture, especially in a country that prides itself on pluralism and individual freedom. For our country to function, citizens must be able to reach

> some common understandings on complex issues, often on short notice and on the basis of conflicting or incomplete evidence (ANAR, 1983, np).

The risk to civic society that scientific illiteracy poses is due to the increasingly complex role of science and technology in society, which "has resulted in complex social issues that must be intelligently addressed by all citizens. Students must be prepared to understand technological innovation, the productivity of technology, the impact of the products of technology on the quality of life, and the need for critical evaluation of societal matters involving the consequences of technology" (EA21C, 1983, p. 44).

The reports position science education as a primary site of training for the new type of citizenship required in the "information" era. For instance, *Educating Americans for the 21st Century* advocates a role for science education in training students how to think in both scientific and non-scientific arenas, because "scientific inquiry and observation presents frequent opportunities for experiencing success with original ideas" (EA21C, 1983, p. 44). Of the seven outcomes of science and technology instruction at the elementary and secondary level in *Educating Americans for the 21st Century* (listed below), only two explicitly address the need for a scientific and technically literate workforce. The others include explicit reference to the needs of future non-scientists as future citizens.

1. Ability to formulate questions about nature and seek answers from observation and interpretation of natural phenomena;
2. Development of students' capacities for problem-solving and critical thinking in all areas of learning;
3. Development of particular talents for innovative and creative thinking;
4. Awareness of the nature and scope of a wide variety of science- and technology-related careers open to students of varying aptitudes and interests;
5. The basic academic knowledge necessary for advanced study by students who are likely to pursue science professionally;

6. Scientific and technical knowledge needed to fulfill civic responsibilities, improve the student's own health and life and ability to cope with an increasingly technological world;
7. Means for judging the worth of articles presenting scientific conclusions (EA21C, 1983, p. 44).

These outcomes articulate scientific literacy as a primary tool for the practice of citizenship – science education should provide tools for public and personal decision-making. Citizens who are scientifically literate "should be able to make informed decisions regarding their own health and lifestyles based on evidence and reasonable personal preferences, after taking into consideration short- and long-term risks and benefits of different decisions. They should also be prepared to make similarly informed choices in the social and political arenas" (EA21C, 1983, p. 44).

These concerns about the future of civic society – and the argument that increased scientific literacy will decrease the risk to democracy and the nation – are echoed in other reports of this time period. For instance, *Missing the Grade*, the Report of the Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy, also published in 1983, and the National Academy of Science's *Indicators of Precollege Education in Science and Mathematics: A Preliminary Review* in 1986 define the scientific illiteracy of non-scientists as a threat to society. A 1983 special issue of *Daedalus* (the official publication of the American Academy of Arts & Sciences) was devoted to exploring the need for scientific literacy in terms of civic society. This special issue was structured around four questions: "Why is such ignorance or "illiteracy" hazardous? How does it impede social and economic progress? What does it do to make certain individuals feel alienated and uncomfortable, never wholly at ease even when not required to cope with complex machines or technologies? Why does such illiteracy have larger implications for the society as a whole?" (Graubard, 1983).

Depicting the Scientifically Illiterate as a Threat in the Media

These anxieties about scientific literacy and citizenship were then reproduced and expanded upon in the mass media publications of the time period. Articles about a lack of public scientific literacy appeared in national newspapers and magazines; local newspapers; specialist publications (e.g. *The Chronicle of Higher Education*) and academic journals; and wire services. These included:

1. National Newspapers and Magazines: *The Boston Globe, The Chicago Sun-Times, The New York Times, The San Francisco Chronicle, U.S. News & World Report, The Wall Street Journal,* and *The Washington Post;*
2. Local Newspapers: *Atlanta Constitution, Atlanta Journal, Austin American Statesman, The Baton Rouge Morning Advocate, The Baton Rouge State Times, The Dallas Morning News, The Houston Chronicle, Newsday, The Orange County Register, The Plain Dealer (Cleveland, OH), Portland Oregonian, The Seattle Times, St. Louis Post-Dispatch, St. Petersburg Times, The Star-Tribune (Twin Cities),* and *Tulsa World*;
3. Specialist Publications: *American Metal Market, Biotechnology Newswatch, The Chronicle of Higher Education, Coal Week, Datamation, Electronic Business Buyer,* and *Science*; and,
4. Wire Services: The Associated Press, Business Wire, Hearst News Service, Knight Ridder Tribune News Service, PR Newswire, and U.S. Newswire.

Articles appeared in multiple sections of these publications: Federal, National, Local, Science; Editorial Columns; Letters to the Editor; and so forth. Headlines included:

> "Scientific Illiteracy: Public lacks grasp of technical issues, studies show"
> – Tom Siegfried (30 June 1986). *The Dallas Morning News*, p.8D
>
> "How scientific should we get? Without scientifically literate citizens, democracy's in peril, educators say"
> – Elizabeth New Weld (21 February 1988). *The Boston Globe*, p. B29
>
> "American School Children Perform Poorly In Science Education, Study Says"
> – Paul Recer (22 September 1988). The Associated Press.
>
> "The dismal state of scientific literacy"
> – Barbara J. Culliton (3 February 1989). *Science*, 243(4891), p. 600.

In these publications, the mass media reinforced and expanded upon the earlier reports on the state of education in the United States by identifying the scientifically illiterate as a threat to civic society.

What discursive patterns can be found in these articles? First, the articles defined the US population as scientifically illiterate. Second, the articles defined scientific illiteracy as a threat to democracy and the effective practice of citizenship. In particular, democracy is understood to be threatened by poor public and private decision-making practices and a growing lack of support of and appreciation for science. Third, writers and those interviewed framed the problem as a new national emergency, and called for governmental intervention modeled on Sputnik era reforms. As in the reports described above, there is an equal if not greater amount of attention given in the articles to the growing chasm between America's science "haves" and "have-nots" and the threats posed by scientific illiteracy to civic society, rather than the country's ability "to produce enough professional scientists to maintain the nation's economic and military strength" (Fiske, 4 January 1987, p. 12). As Fiske (1987) continued, "Today there is little concern expressed about the nations capacity to produce scientists. The field has intrinsic appeal to bright students, who are frequently identified at a young age. The best high schools offer first-rate science courses, and graduate fellowships are readily available to college science majors. Salaries in industry are competitive, and while scientists complain about cutbacks under the Reagan Administration, the level of scientific research remains high." However, though "the flow of future Nobel Prize winners and other scientists seems assured, concern is rampant about the science illiteracy of the public, which must understand and manage what scientists develop" (Fiske, 4 January 1987, p. 12).

In the articles, the US public is defined as scientifically illiterate through media coverage of quantitative national and international surveys of the scientific literacy of school-age and adult populations. These studies include those conducted by the National Science Board (1986, 1988) and *The Science Report Card: Elements of Risk and Recovery* (Mullis & Jenkins, 1988). For instance, the 1987 *New York Times* article by science reporter Edward Fiske includes data reported by Jon Miller, then director of the Public Opinion Laboratory at Northern Illinois University, and author of biannual reports on the public understanding of science in the National Science Foundation's *Science and Engineering Indicators*, about the results of a scientific literacy survey of two thousand adults:

> more than two out of five agreed that "Space shots have caused changes in our weather." A comparable proportion said that "Some numbers are especially lucky for some people." More than a third of those interviewed also agreed that "Science tends to break down people's ideas of right and wrong" … [and that] large numbers of Americans do not understand basic scientific terms such as "molecule" and "radiation" (Fiske 4 January 1987, p. 12)

The *Friel Study* (1987), as reported in numerous mass media articles, found that, "American students are outclassed in advanced physics, chemistry and biology by students in England, Japan and six other industrialized countries" (Coons, 25 October 1987, p. 7). Numerous articles were also published in response to a third study, *The Science Report Card: Elements of Risk and Recovery*, a federally funded assessment conducted by the Educational Testing Service, released in 1988 and based on data collected in 1986. For instance, Associated Press writer Paul Recer reported that, "more than half of the nation's 17-year-olds are so poorly educated in science that they cannot benefit from special job training and cannot perform work requiring basic technical understanding. Only seven percent of the 17-year-olds in the study demonstrated sufficient skills to do well in college-level science courses" (Recer, 22 September 1988).

The 1988 report by the NSF on the public understanding of science (again conducted by Jon Miller) provided more data for this image of the US public as scientifically illiterate. As reported by the Associated Press, a telephone survey of over 2000 adults in which participants were asked 75 basic science question showed that "vast numbers of Americans are scientifically illiterate" and only 5-7% of the US population could be categorized as scientifically literate. For instance,

> To the question about whether the Earth goes around the sun or the sun around the Earth, 21 percent replied incorrectly. Seven percent said they didn't know. Of the 72 percent who answered correctly, 45 percent said it takes one year for the Earth to orbit the sun, 17 percent said one day, 2 percent said one month and 9 percent didn't know. The responses indicate that about 55 percent of adult Americans, or some 94 million people, don't know that the Earth revolves around the sun once a year (Associated Press, 24 October 1988, p. 3A).

In more specialized publications like *Science*, this same type of data was reported as an accurate description of the US public. For instance, Barbara Culliton's 1989 article entitled, "The Dismal State of Scientific Literacy," reported that "Well under half of the American public and only one-third of the British know that the earth revolves around the sun once a year"; that "Most of the people surveyed think that antibiotics kill viruses"; that only 88% of the US public thinks that astrology is "not at all scientific"; and that "about 35% of both Americans and British think that radioactive milk can be made safe by boiling" (Culliton, 3 February 1989, p. 600). A second 1989 article in *Science* reported that, "a new international study shows that U.S. 13-year-olds are at or near the bottom of the pack when it comes to math and science achievement. American students placed dead last in math achievement, behind four foreign countries and four Canadian provinces. They fared little better in science achievement, ranking among the bottom four groups studied" (Byrne, 10 February 1989, p. 729)

As reported in multiple articles, the results of these surveys were described as "depressing and alarming" and "disastrous" for the country by Albert Shanker, then president of the American Federation of Teachers. Mary Hatwood Futrell, then president of the National Education Association, "said the findings 'paint a stark picture of science education in our nation's schools'" (Recer, 22 September 1988). Jon Miller described the results as indicating a "a fairly dire situation"

(Associated Press, 24 October 1988, p. 3A), and Bassam Shakhashiri, then assistant director for science and engineering education at NSF, said that the reports were "nothing short of frightening" (Byrne, 10 February 1989, p. 729). In part, the results of the surveys were understood to be disastrous because of the dangers posed to the future workforce and members of the armed forces, who would be required to be scientifically and technically literate (for example: Fiske, 4 January 1987, p. 12; Siegfried, 21 November 1988, p. 6D; Roan, 2 March 1989, p. K01; Watkins 28 July 1989, p. 14). However, like the national reports described above, mass media coverage also emphasized the threats to democracy that the scientific illiteracy of non-scientists posed and the need for all citizens to be scientifically literate. For example, a 1986 article reported that Jon Miller said that current levels of scientific literacy don't meet "the basic test of democracy, because we really have a lot of important science policy issues that at some point are going to have to be decided and ought to have some democratic input" (Siegfried, 30 June 1986, p. 8D). A 1987 article by Edward Fiske in *The New York Times* raised similar concerns:

> Citizens are routinely finding themselves facing decisions that require scientific judgments -from national policies on nuclear power and "Star Wars" to personal decisions about the risks of sexually transmitted diseases. But there is uneasiness that many Americans are ill equipped by their science educations to make such decisions intelligently (Fiske, 4 January 1987, p. 12).

Fiske quoted Robert Pollack, a molecular biologist and then dean of Columbia College, as saying that, "Letting the experts run things is not appropriate for a democracy ... American citizens have an obligation to understand things, and that means becoming scientifically literate… For an individual, knowing how to ask the right questions is part of being educated. … For a democratic society, empowering people to do this is a fundamental responsibility" (Fiske, 4 January 1987, p. 12). Roger B. Nichols, then director of the Boston Museum of Science, told *The Boston Globe* that, "Democracy is a fragile flower … Americans who don't understand the benefits as well as the risks of technology will not be able to make decisions at the ballot box that can move this country forward" (Coons, 25 October 1987, p. 7). The writers of *The Science Report Card* (Mullis & Jenkins, 1988) concluded, as reported in *The Dallas Morning News* and other articles, that the poor scientific literacy results "have serious implications for students' adult lives – including how they will be able to participate in society as informed voters and decision-makers, perform everyday tasks, express intelligent points of view and contribute to the nation's economic future" (Macias, 11 October 1988, p. 1A). Mary Hatwood Futrell, then president of the National Education Association, responded to *The Science Report Card* by stating that, "If America's citizens of tomorrow are not scientifically literate, we place our very democracy at risk" (Recer, 22 September 1988).

The mass media articles linked scientific literacy to "effective citizenship" (Culliton, 3 February 1989, p. 600) and described scientific illiteracy as a threat to democracy for a number of specific reasons. Primarily, scientific illiteracy was linked to irrational and uninformed public and private decision-making practices on the part of non-scientists. Such poor public and private risk assessment was seen to threaten not only democracy, but also science, itself, through a growing lack of support for and appreciation of science. The dual-threat to democracy and to science threatened the future of the nation and jeopardized its standing in the world. Both Jon Miller and Bassam Shakhashiri consistently focused during this time period on the perils of ill-informed public and private decision-making in making their case that scientific illiteracy threatens democracy. In the mass media, Miller frequently pointed to the example of people boiling their milk before they drank it following the Chernobyl reactor accident, which he said demonstrated their misunderstanding of radioactivity (for instance: Weld, 17 May 1987, p. 110). In 1988, Shakhashiri said that the "situation [of scientific illiteracy] should not be tolerated." He continued:

> We need to have an educated citizenry that understands the complex issues related to pollution control. We need an educated citizenry that can distinguish between astronomy and astrology. We need an educated citizenry that appreciates the complex issues related to nutrition. And the list goes on and on and on. … The purpose of improving the quality of science education in this country is not to beat the heck out of the Japanese or West Germans or any of the industrialized nations that are ahead of us. The main purpose is to ensure that we as a society do not get bamboozled into making foolish decisions (Siegfried, 21 November 1988, p. 6D).

The question, for Shakhashiri, was "do we have the will, do we have the determination to deal with those issues. If we don't, we very quickly will become a second-rate nation" (Siegfried, 21 November 1988, p. 6D).

In these mass media discourses, science literacy is described as allowing citizens to "function appropriately in society" (Roger L. Nichols, then director of the Boston Science Museum in Weld, 17 May 1987, p. 110). For Nichols, the public's need to be scientifically literate is a relatively new phenomenon, "not that significant before World War II." Other articles and prominent figures also focused closely on the problems of scientific illiteracy and risk assessment. In 1987, science reporter Edward Fiske wrote that, "Examples abound of scientific findings having an impact on social, political and personal judgments. A California court is now involved in the issue of whether it is safe to spray potato plants with genetically engineered bacteria in an effort to protect them from frost. … Many scientists believe that, because of excessive fears about the dangers of nuclear power plants, the United States will eventually find itself falling behind other countries" (Fiske, 4 January 1987, p. 12). In the same article, George Bugliarello, then president of Polytechnic University, in Brooklyn, focused on questions about power generation and pollution: "It's important for people to understand that there are trade-offs involved in any kind of power… The dangers of nuclear power are well known, but less known is the fact that coal causes acid rain." Noting that pollution problems in Vermont are the result of coal-burning stoves, he continues: "It's fine to say that small is beautiful …. But the scientifically literate person also recognizes the collective impact of many small actions" (Fiske, 4 January 1987, p. 12).

According the these discussions of scientific illiteracy in the mass media, this threat to democracy due to ill-informed public and private decision-making and risk assessment practices is also a threat to science because of decreasing public support for and appreciation of science. Increasing scientific literacy was described as a way to increase support for science. For instance, in February 1988, Bassam Shakashiri argued that, "Scientists are like athletes who have been developing their game but now need to develop fans. … The scientific community must focus not only on future scientists but also on an enlightened citizenry," that would appreciate and understand science (Weld, 21 February 1988, p. B29). Later that year, Shakashiri again used this metaphor to emphasize this point: "[W]e need to have a good supply of scientists and engineers and we need a supporting environment for the scientists and engineers to work in" (Siegfried, 21 November 1988, p. 6D). Again, in 1989, Shakhashiri spoke about this issue:

> We have a twofold mission. We must increase the flow of talent into science, math and engineering, and we must increase the science literacy of the public at large. At stake is the ability of the United States to remain a first-rank economic, political and scientific leader.… Just as the nation has knowledgeable fans who support professional baseball, basketball and football teams, it needs science fans who are mentally fit. … We want our fans to behave in a rational way - not like the behavior of some soccer fans in Europe and Latin American. We need good, analytical players and audiences that appreciate what the players are doing (Allen, 5 November 1989, p. 1C).

F. James Rutherford, then chief education officer for the American Association for the

Advancement of Science, also shared this concern, stating: "Help give all the kids a better science education and you'll have enough scientists and engineers…. Concentrate on getting your share of physicists and mathematicians, and we may not get them – or we may – but we'll have a society that won't know how to support them and use their products and knowledge" (Siegfried, 21 November 1988, p. 6D). In all of these examples, democracy is at risk because the public is not behaving appropriately in relation to science and scientists – they are not being good citizens because they are not making appropriate private and public decisions about science and technology; they are not being enlightened citizens because they are not supporting scientific and technical development.

The mass media portrayed a need for a visible response to the threat posed by scientific illiteracy, both on the part of the national and state governments, as well as corporations. In part, this was done by naming scientific illiteracy as a national emergency. For instance, David Hamburg, then president of the Carnegie Corp. of New York and outgoing AAAS chairman described the situation as similar to "unilateral disarmament to give up on education and in particular science education" (Siegfried, 30 June 1986, p. 8D). Margaret MacVicar, then dean for undergraduate education at the Massachusetts Institute of Technology, indicated that she would "like to see a national emergency declared" (Siegfried, 30 June 1986, p. 8D). Betty Vetter, then executive director of the Commission on Professionals in Science and Technology stated that, "We can't wait any longer to take drastic action to improve science literacy. Otherwise, as a nation we're finished" (Smetanka, 24 September 1988, p. 01B). One common strategy to bolster the claims of a national emergency was to draw a parallel between the current state of scientific illiteracy and the Soviet launch of Sputnik in 1957 (including the 1958 National Defense Education Act). As Bassam Shakharishi stated in 1989, "Sputnik was perceived as a national security threat, and the country responded … our response can be no less emphatic" (Higgins, 23 March 1989, p. 1). However, in contrast with the Sputnik-era reforms, there was a call for a shift in national focus from scientists to non-scientists as the primary target of science education reform. For instance, George Tressel, then division director of materials development for the National Science Foundation, stated that, "This time we're focusing on little people, not little scientists, although we hope some of them will turn into little scientists" (Weld, 30 January 1987, p. B).

FORMAL SCIENCE EDUCATION FOR SCIENTIFICALLY LITERATE CITIZENSHIP

Throughout the 1980s and 1990s, many types of organizations began to respond to the identification of the threat to the nation caused by scientific illiteracy. These groups included governmental policymakers; science education researchers; and educators and curriculum developers. In 1989, for instance, the National Governors Association adopted six National Education Goals for students in grades K-12. These goals later became a part of President George H.W. Bush's *America 2000: An Education Strategy* program (1990) and were enacted at the legislative level in 1994 during Bill Clinton's presidency in the *Goals 2000, Educate America* Act (Collins, 1998, p. 713). Two of the goals deal directly with science education and citizenship.

> **Goal 3: Student Achievement and Citizenship**
> By the year 2000, American students will leave Grades 4, 8, and 12 having demonstrated competency in challenging subject matter, including English, mathematics, science, history, and geography; and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning and productive employment in our modern economy.
>
> **Goal 4: Science and Mathematics**
> By the year 2000, U.S. students will be first in the world in science and mathematics achievement. (Malcolm, 1993, p. 4) (cited in Collins, 1998, p. 713).

Central to both *America 2000* and *Goals 2000* were the creation of national education standards and testing – standards to "incorporate both knowledge and skills, to ensure that, when they leave school, young Americans are prepared for further study and the work force" and "tests to foster good teaching and learning as well as to monitor student progress" (*America 2000*, cited in Spring, 1998, p. 138).

The science education research community also shared many of the concerns about the interconnections between scientific literacy and citizenship previously discussed. Rüdiger Laugksch's (2000) summary of the perspectives of science education researchers on scientific literacy in the late 1980s, drawn primarily from Geoffrey Thomas and John Durant (1987) and Michael Shortland (1988) shows how the science education research community linked scientific literacy to "alleged benefits that accrue to the nation, science, or society" (the macro-level) and the "enhancement of the lives of the individual" (the micro-level) (Laugksch, 2000, p. 84). Laugksch describes the macro goals as including first, the promotion of the economic well-being of the nation and its successful competition in the global marketplace via scientific and technical research and development. Success in this arena requires (a) a strong science, technology, engineering, and mathematics (STEM) workforce; (b) increased public support for science made visible via increased public monies directed towards science – scientific literacy as the "antidote to anti-science" (Courderc, 1971); and, (c) the simultaneous development of realistic public expectations for science and scientists – to counter the possibility of the public's disenchantment with science and a withdrawal of funding. Second, macro-level arguments for scientific literacy focus on the promotion of public participation in the decision and policy-making process as technically "savvy" citizens (Prewitt, 1983). Thomas and Durant, for instance, wrote that the increased scientific literacy of all citizens,

> … may be able to promote more democratic decision-making (by encouraging people to exercise their democratic rights), which may be regarded as good in and of itself; but in addition, it may be thought to promote more effective decision-making (by encouraging people to exercise their democratic right *wisely* [emphasis added] (Thomas and Durant, 1987, pp. 5-6, cited in Laugksch, 2000, p. 85).

Third, improved scientific literacy was understood to lead to the integration of science and the wider culture to counter the specialist and highly technical image of science, which was seen as leading to both adulation and fear (Laugksch, 2000, pp. 84-85). At the micro-level, improved scientific literacy was seen by science education researchers as a requirement for successful living in an increasingly science and technology dominated society. Equipped with greater knowledge, scientifically literate citizens would be able to make better personal decisions in regards to their own and their family's health, safety, consumption and use of products, etc. Second, these citizens would have improved access to jobs that require scientific and technical knowledge (and can better serve the economy). Third, because science was understood as being a part of the intellectual, aesthetic, and moral cultures of the present (Laugksch, 2000, p. 86) – that is, a component of cultural literacy (Hirsch, 1987) – scientific literacy "would make people not merely wiser but better" (Shortland, 1988, p. 33).

Finally, national bodies of science educators and curriculum developers such as the American Association for the Advancement of Science, the National Science Teachers Association, and the National Academy of Sciences were preparing curriculum-based responses to the crisis in scientific literacy to end the threat to democracy and the nation. These new science education standards were a direct response to the to the escalating anxiety about the levels of scientific literacy of non-scientists in the United States and to the environment of risk that was identified in the 1983 reports and expanded upon in the mass media. The standards and reform documents emphasize that scientific literacy is necessary for all students, position scientific education as a site of training for future citizens, and situate scientific literacy as a prerequisite for being a good citizen.

In 1985, AAAS established Project 2061 "to help all Americans of literate in science, mathematics, and technology." In 1989, AAAS published *Science for All Americans*, based on the recommendations of "expert panels of scientists, mathematicians, and technologists." It "set out recommendations for what all students should know and be able to do in science, mathematics, and technology by the time they graduate from high school" and "laid the groundwork for the nationwide science standards movement of the 1990s." In 1993, AAAS published *Benchmarks for Scientific Literacy*, which "translated the science literacy goals in *Science for All Americans* into learning goals or benchmarks for grades K–12." The recommendations in *Benchmarks for Scientific Literacy* "suggest reasonable progress toward the adult science literacy goals laid out in the project's 1989 report *Science for All Americans*." At the same time, in 1992, the National Science Teachers Association published the content core of its *Scope, Sequence, and Coordination* Project, aimed at reforming grades 6-12 science education to meet the goals of scientific literacy for all. The National Academy of Sciences (specifically the National Research Council), at the behest of the federal government, NSTA and AAAS, began work in 1991 on developing national standards for science education, which were eventually published in 1996 as the *National Science Education Standards*.

Empirically, the new national and international science education reform documents and standards share much in common with each other. Okhee Lee's (1998) comparative analysis of Project 2061 and the NSES with the new assessment systems, including the New Standards Project (National Center on Education and the Economy, 1997a, 1997b, 1997c), the National Assessment of Educational Progress (National Assessment Governing Board, 1994, 1996), and the Third International Mathematics and Science Study (International Association for the Evaluation of Educational Achievement, 1995, 1999), indicates that:

> Together, these documents define science achievement in a comprehensive manner. Science achievement, i.e., what K-12 students should know and be able to do, includes concepts and theories in physical, life, and earth and space sciences; scientific inquiry or investigation; science with mathematics and technology; science in personal and social perspectives; the nature and history of science; unifying

> concepts or common themes; and scientific habits of mind. In addition, these documents define science achievement at different developmental levels (i.e., generally at elementary, middle, and high school years) and at certain depths of knowledge and abilities for all students (Lee, 19998, p. 12).

I have reproduced Lee's (1998) table on "Science Achievement: An Aggregated View from Major Reform Documents" to show the similarities and relationships between these key documents (**Table 1**). For the purposes of my discussion here, I will primarily focus on the ways in which science education for future citizens is portrayed in these documents, rather than focusing on agreements and disagreements on the content standards, or rehearsing what the content standards for each grade level are.

In all of these initiatives, the groundbreaking work of AAAS's Project 2061 and its emphasis on "science for all" has played a dominant role at the state and national levels. A 1996 evaluation of Project 2061 by Zucker, et al, found that "many state curriculum documents cite Project 2061 and its publications as key sources in their bibliographies, quote directly from the project's publications, or organize their own recommendations to parallel the 2061 documents. Some even adopt benchmarks verbatim" (AAAS, 2005, np). According to AAAS (1996, 1997), there is a 90% agreement in content standards between the National Science Education Standards and Project 2061 documents (cited in Lee, 1998, p. 12), and the National Science Education Standards include the statement that the "use of Benchmarks … complies fully with the spirit of the [NSES] content standards" (NSES, 1996, p. 15). Project 2061 documents have also been used in the development of the Statewide Systemic Initiatives program of the National Science Foundation, the Department of Education's Eisenhower Mathematics and Science Education Program, and the Association for Supervision and Curriculum Development (AAAS, 2005, np).

Table 1: Science Achievement: An Aggregated View from Major Reform Documents (Lee, 1998)

	Components	Indicators	Document Sources
Content	**Physical Science** **Life Science** **Earth & Space Science**	• Key concepts and theories • Key vocabulary	All
	Science, Mathematics, and Technology		
	Mathematics	• Measurement concepts • Statistics and probability concepts	Project 2061, TIMSS
	Technology	• Engineering and design	All
	Personal and Social Perspectives	• Health • Population growth • Natural resources • Environmental quality • Safety and hazards	NSES, Project 2061, TIMSS, New Standards
	History and Nature of Science		
	History of Science	• Historical developments and major discoveries • Contributions of diverse cultures	All
	Nature of Science	• Nature of scientific knowledge • Nature of scientific inquiry • The scientific worldview	All
	Unifying Themes	• Systems • Models • Constancy and change • Evolution and equilibrium • Form and function	NSES, Project 2061, NAEP, New Standards
Process	**Scientific Understanding**	• Key concepts and theories • Relationships among concepts and theories • Explanations of natural phenomena • Applications to new situations	All
	Scientific Investigation	• A systemic observation, a fair test, or a controlled experiment	All
	Scientific Communication	• Multiple representations • Rules of the discourse of science	NSES, Project 2061, TIMSS, New Standards
	Scientific Habits of Mind	• Values and attitudes	NSES, Project 2061

Why scientific literacy for all? Why scientific literacy for citizenship? *Science for All Americans*[2] consists, as stated in its first paragraph, of "a set of recommendations on what understandings and ways of thinking are essential for all citizens in a world shaped by science and technology" (SFA, 1989, np). The National Science Education Standards,[3] similarly, "are standards for all Americans: Equity is an underlying principle of the Standards and should pervade all aspects of science education" (NSES, 1996, p. 16). According to *Science for All Americans,* science literacy for all is necessary because:

> Education has no higher purpose than preparing people to lead fulfilling and responsible lives. For its part, science education—meaning education in science, mathematics, and technology—should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital. America's future—its ability to create a truly just society, to sustain its economic vitality, and to remain secure in a world torn by hostilities—depends more than ever on the character and quality of the education that the nation provides for all of its children (SFA, 1989, np).

The National Science Education Standards also recognize that, "An important purpose of science education is to give students a means to understand and act on personal and social issues (NSES, 1996, p. 107). And the NSTA's Project on Scope, Sequence, and Coordination, affirms that, "In this country, we teach science only to the elite, and we somehow assume that others cannot learn

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[2] In this chapter, references from *Science for All Americans* use the following notation in parenthetical citations: **SFA**.
[3] In this chapter, references from the *National Science Education Standards* use the following notation in parenthetical citations: **NSES**.

science…. But science is needed by everyone and everyone is capable of learning and enjoying science" (NSTA, 1992, pp. 13-14).

As *Science for All Americans* continues, scientific literacy is necessary to inform decision-making about global problems, such as:

> unchecked population growth in many parts of the world, acid rain, the shrinking of tropical rain forests and other great sources of species diversity, the pollution of the environment, disease, social strife, the extreme inequities in the distribution of the earth's wealth, the huge investment of human intellect and scarce resources in preparing for and conducting war, the ominous shadow of nuclear holocaust—the list is long, and it is alarming (SFA, 1989, np).

While there is recognition in the documents that science and technology have had harmful impacts on the environment, science and technology are predominantly portrayed as capable of providing life-enhancing solutions to global and local problems through scientific knowledge production, technological development, and a better understanding of the natural world.

- Science, energetically pursued, can provide humanity with the knowledge of the biophysical environment and of social behavior needed to develop effective solutions to its global and local problems; without that knowledge, progress toward a safe world will be unnecessarily handicapped.
- By emphasizing and explaining the dependency of living things on each other and on the physical environment, science fosters the kind of intelligent respect for nature that should inform decisions on the uses of technology; without that respect, we are in danger of recklessly destroying our life-support system.
- Technological principles relating to such topics as the nature of systems, the importance of feedback and control, the cost-benefit-risk relationship, and the inevitability of side effects give people a sound basis for assessing the use of new technologies and their implications for the environment and culture; without an understanding of those principles, people are unlikely to move beyond consideration of their own immediate self-interest. (SFA, 1989, np)

As *Science for All Americans* continues, without support for science and technology, "society may limit its capacity for survival and for working toward a world in which the human species is at peace with itself and its environment" and "The life-enhancing potential of science and technology cannot be realized unless the public in general comes to understand science, mathematics, and technology and to acquire scientific habits of mind. Without a science-literate population, the outlook for a better world is not promising" (SFA, 1989, np).

Within the new standards and reform documents, scientific literacy means that students will adopt scientific habits of mind. Scientific habits of mind for non-scientists play an important role in *Science for All Americans*, for instance, because:

> *Science for All Americans* is based on the belief that the science-literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (SFA, 1989, np).

Further, development of scientific habits of mind allows individuals "to move beyond consideration of their own immediate self-interest" (SFA, 1989, np). "Scientific habits of mind can help people in every walk of life to deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty" (SFA, 1989, np). Without scientific habits of mind, according to the new standards and reform documents, individuals do not have the "ability to think critically and independently" (SFA, 1989, np). Instead, "citizens are easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems" (SFA, 1989, np).

These scientific habits of mind can be developed, according to the documents, through exposure to the history and the nature of science because the history and the nature of science highlight scientific processes that can then be transferred to everyday practices of public and private decision-making through habits of mind and adoption of the scientific worldview. The history of science within the documents is defined as the history of Western Science since Copernicus. *Science for All Americans* includes ten episodes from the history of science: "Displacing the Earth from the Center of the Universe" (Aristotle, Ptolemy, Copernicus, Kepler, Galileo); "Uniting the Heavens and Earth" (Newton); "Relating Matter & Energy and Time & Space" (Einstein); "Extending Time" (Charles Lyell); "Moving the Continents"; "Understanding Fire" (Lavoisier, John Dalton); "Splitting the Atom" (Marie & Pierre Curie, Ernest Rutherford, Lise Meitner, Otto Frisch); "Explaining the Diversity of Life" (Darwin, Mendel); "Discovering Germs" (Pasteur); and "Harnessing Power" (James Watt).

The nature of science included in the new standards and reform documents, which includes the nature of scientific knowledge, the nature of scientific inquiry, and the scientific worldview, likewise depends on Western scientific practice. A 1998 comparative study of eight curriculum standards documents including *Benchmarks for Scientific Literacy,* the *National Science Education Standards*, the California State Standards, and National Curricula in Australia, New Zealand, Canada, and England and Wales found near consensus on the following themes on the nature of science: 1) scientific knowledge is tentative; 2) science relies on empirical evidence; 3) scientists require replicability and truthful reporting; 4) science is an attempt to explain phenomena; 5) scientists are creative; 6) science is part of social tradition; 7) science has played an important role in technology; 8) scientific ideas have been affected by their social and historical milieu; 9) changes in science occur gradually; 10) science has global implications; and 11) new knowledge must be reported clearly and openly (McComas and Olson, 1998).

THE CONSTRAINTS OF SCIENTIFICALLY LITERATE CITIZENSHIP

The previous two sections of this chapter mapped the rise and policy-level resolution of a moral panic about scientific illiteracy that emerged in the United States in the 1980s by undertaking an analysis of three different types of materials from the 1980s that identified scientific illiteracy as a threat to the nation and democracy. First, reports on the state of education in the US published in the early 1980s identified scientific literacy as a growing threat to the social order in the United States in economic, military, and civic arenas. Second, these anxieties about scientific literacy and non-scientists were then reproduced and expanded upon in the mass media publications of the time period. These articles stressed the shocking nature of the scientific illiteracy and the growing numbers of adults and school-age persons unable to distinguish science from pseudo-science. The publications then linked scientific illiteracy to threats to US democracy and to the effective practice of citizenship by non-scientists. In particular, anxieties about scientific literacy and civic life centered on poor public and private decision-making practices, and a growing lack of support of and appreciation for science. Publication authors and those interviewed in the mass media publications framed the problem as a new national emergency, and called for governmental intervention modeled on Sputnik era reforms. Finally, in the late 1980s and 1990s, new national science education standards and reform documents were created by organizations including the American Association for the Advancement of Science, the National Science Teachers Association, and the National Research Council. These documents responded to the moral panic about scientific illiteracy by redefining the purpose of science education as the education of all students to be scientifically literate and positioning scientific literacy as a prerequisite for citizenship practices, including personal and public decision-making.

What is the political meaning of scientifically literate citizenship? Who is scientifically illiterate? What model of citizenship does formal science education normalize for future non-scientists? As described above, the scientifically illiterate are numerous, and are identified in two ways. First, they are identified through quantitative testing and surveys, such as those surveys completed by the NSF on the public understanding of science: "Well under half of the American public and only one-third of the British know that the earth revolves around the sun once a year"; "Most of the people surveyed think that antibiotics kill viruses"; only 88% of the US public thinks that astrology is "not at all scientific"; and "about 35% of both Americans and British think that radioactive milk can be made safe by boiling" (Culliton, 3 February 1989, p. 600). Second, the scientifically illiterate are identified by the poor decisions they make, by their inability to function appropriately. For instance, scientifically illiterate citizens question the genetic modification of bacteria and nuclear power: "Cambridge almost voted out genetic engineering, where Harvard and MIT are the centers of the research. And no one can understand Three Mile Island without an understanding of radiation" (Weld, 17 May 1987, p. 110). Scientifically illiterate citizens also show themselves by their inability to assess risks, by their use of qualitative rather than quantitative judgment: "Risk assessment is always a quantitative one… Without a scientific understanding, people respond to dramatic, isolated incidents that are not high risks, when the real high-risk activities such as smoking and auto accidents go comparatively unremarked. [For instance, in auto accidents,] "50,000 people a year die from not wearing their seat belts, but, if someone raises an alarm about sharks or rabies, he said, everyone reacts (Weld, 17 May 1987, p. 110).

Previous analyses of efforts to increase adult public understanding of science in the United Kingdom have described the ways in which these educational efforts rely on a deficit model of science education As described by Alan Irwin and Brian Wynne this model begins with:

> an apparent assumption of 'public ignorance' in matters of science and technology – an assumption which has been bolstered by recent questionnaire surveys. According to these, the general public often lacks a basic understanding of scientific facts,

> theories and methodologies. Public controversy over technical issues is created by inadequate public understandings rather than the operation of science itself (Irwin & Wynne, 1996, p. 6).

As Irwin and Wynne suggest, the deficit or 'public ignorance' model of public understanding of science creates boundaries between the public and science and scientific institutions, and focuses the attention of analysts, policymakers, the news media, science educators, and so on, only on the problematic/problematized public – begging the question, "just why aren't the public more responsive?" (Irwin & Wynne, 1996, p. 6). Two additional assumptions are present: 1) science is assumed to be "an important force for human improvement, … offering a uniquely privileged view of the everyday world"; 2) science is always described and imagined as a value-free and neutral activity (Irwin & Wynne, 1996, p. 6).

The model of appropriate scientifically literate citizenship found in the US moral panic about scientific illiteracy in the 1980s and the solution enacted in the national science education reform documents in the late 1980s and 1990s shares some of the features of the deficit or public ignorance model of science education, but differs in other important ways. In both cases, it is the non-scientists that must be 'fixed', not science or the policy-making process or values that underlie both science and policy. As well, the public ignorance model is present, particularly in media coverage of the large-scale quantitative surveys completed by the NSF on the public understanding of science. However, a second model of science education for scientific literacy is more pre-dominant. This second model is process-based. In this model, future non-scientist citizens must be trained to "think like scientists," so that they may think rationally and use quantitative risk assessment in their personal and public decision-making processes. Non-scientist citizens must develop "scientific habits of mind" and adopt the "scientific worldview" through exposure to the history and the nature of science. Notably, the history and the nature of science are exclusively Western Science, training non-scientists to demarcate between the scientific, rational ways of knowing and all others by reinforcing an emphasis on "explaining, predicting, and controlling nature" and an "emphasis on independence and individuality" (Lee, 1999). In these ways, citizens are trained to actively participate in demarcating between science and non-science, experts and non-experts, rationality and irrationality, and so forth. This model of scientifically literate citizenship is based on a theory of acquiescent democracy, in which citizens actively acquiesce to the authority of science and the state because they have been trained to believe this is the only option for rational behavior. To question science is to be scientifically illiterate.[4]

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[4] A second key difference between the US model of training scientifically literate citizens and the deficit model of science education, as developed by Irwin & Wynne, is that, in the US context, science is not presumed to be value-free. Instead, through training in the history and the nature of science, future non-scientists are supposed to adopt the values of science to guide their personal and public decision-making. What are the values in science? According to the national science education standards, scientists are creative, science is part of social tradition, and scientific ideas have been affected by their social and historical milieu. Thus, the history and nature of science presented in the national science education standards does not assume that scientific change is motivated solely by empirical evidence and the search for truth (thus the history and nature of science provided is not 'internalist'). However, the history and nature of science presented in the national science education standards is 'progressive' (in the "Whig" sense), in that it follows a linear model of scientific development in which the history of science is assumed to have led towards (or culminated) in today's scientific understandings, and that today's science is leading towards complete knowledge of the natural world (see Shapin, 1982).

Douglas Alchin's (1995) analysis of the history of science found in *Science for All Americans* indicates that, while it "is sometimes cited as a progressive standard on historical perspectives in science education," *Science for All Americans* actually "reflects conservative practice" (Alchin, 1995, np).

> Its ten episodes celebrate scientific contributions and great scientists. Science is thus primarily product, not process. While the standards aim to portray scientific knowledge as fallible, they also convey its authority and disguise the difficulties of exposing error. Likewise, they portray science as human, but also as relying on a few exceptional, superhuman individuals (who are almost exclusively Western males). Such uses of history have deep philosophical and ideological overtones (Alchin, 1995, np).

Karan Barad (2000) writes that the history and nature of science found within the science education reform documents "often reenact the very problem they are trying to address by pulling only single strands of history or philosophy out of a complex cloth in order to patch together a background against which to view science" and "play off an assumed nature/culture dualism, reifying one pole or the other in an attempt to identify linear causal lines of influence between science and culture" (Barad, 2000, p. 227). This progressive history of science relies, as well, on an assumption that the values currently associated with science are the values that

Why does such a marked difference exist between what are often described as parallel efforts in the US and UK to intervene in scientific literacy (aka, the public understanding of science) in the 1980s? This difference, again, highlights the importance of attending to the specific sociocultural contexts from which today's dominant science education theories and practices have emerged. In her most recent book, Sheila Jasanoff (2005) examines sociocultural patterns of civic engagement with science and the state within the UK, US, and Germany. She argues that, "how publics assess claims by, on behalf of, or grounded in science forms an integral element of political culture in contemporary societies" (Jasanoff, 2005, p. 249). These "civic epistemologies" describe those "culturally specific, historically and politically grounded, public knowledge ways" (Jasanoff, 2005, p. 249) – that is, how trust, credibility, and expertise are established in different cultural contexts. [I should note that Jasanoff differentiates her project from more typical comparisons of "national character," arguing that while she employs the concept of nation-state for comparative purposes, this category is premised on a "dynamic concept of political culture, rather than the more static categories of political actors, interests, or institutions" (Jasanoff, 2005, p. 15).]

Jasanoff's analysis focuses on six dimensions of civic epistemology: (1) the dominant participatory styles of public knowledge-making; (2) the methods of ensuring accountability; (3) the practices of public demonstration; (4) the preferred registers of objectivity; (5) the accepted bases of expertise; and (6) the visibility of expert bodies (2005, p. 259). Briefly, Jasanoff describes British civic

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should be part of this process (i.e., the "is-ought" fallacy) – that is, that scientific knowledge production as it currently happens works well. Finally, the progressive history of science relies on a distinction between the individual scientist (who may operate with the 'wrong' values) and the scientific community – where processes such as peer review and replication studies are presumed to weed out 'bad' science created with the 'wrong' values. In these ways, the autonomy and privilege accorded to science are maintained in the US context despite the role of values in science.

epistemology as communitarian; German civic epistemology as consensus-seeking; and US civic epistemology as contentious (2005, p. 250). (See Table 2 for a summary.)

Table 2: Civic Epistemologies – A Comparative View (Source: Jasanoff, 2005, p. 259)

	United States Contentious	**Britain Communitarian**	**Germany Consensus-seeking**
Styles of public knowledge-making	Pluralist, interest-based	Embodied, service-based	Corporatist, institution-based
Public accountability (basis for trust)	Assumptions of distrust; Legal	Assumptions of trust; Relational	Assumption of trust; Role-based
Demonstration (practices)	Sociotechnical experiments	Empirical science	Expert rationality
Objectivity (registers)	Formal, numerical, reasoned	Consultative, negotiated	Negotiated, reasoned
Expertise (foundations)	Professional skills	Experience	Training, skills, experience
Visibility of expert bodies	Transparent	Variable	Nontransparent

Here, I would like to draw attention to some of the characteristics of the US and UK models of civic epistemology that that may be useful in explaining why scientific literacy efforts in the 1980s looks so different in each of these countries. While a 2000 House of Lords report in the UK promoted increased opportunities for public participation in scientific and technical decision-making practices, citizens have had historically relatively fewer opportunities in the UK than the US to participate due to the ways in which trust, expertise, and credibility are differently constituted in these countries. For instance, while members of the public in the US have access to the deliberations and products of expert committees and governmental bodies, there has been no guarantee of transparency in the UK's scientific and technical decision-making practices. Instead, each committee in the UK may choose whether or not to make any part of its deliberations public.

This transparency (or lack thereof) relates directly to the ways in which public knowledge comes to count as trustworthy and credible in the different countries. In the US, according to Jasanoff, public knowledge becomes trustworthy only following stringent "testing" within the public sphere by the court system (where citizens can bring lawsuits), in the media, and by citizen groups. As well, public knowledge put forward by the state operates as only one source of knowledge in the US. Rather, because knowledge production is understood as pluralist and interest-based, groups such as academic researchers and NGOs can produce and distribute competing forms of knowledge, that are likewise subject to public testing. In terms of the constitution of expertise, "professional skills and standing are emphasized, based on the idea of meritocracy," in which "anyone can become an expert by climbing the ladder of professional success" (Jasanoff, 2005, p. 268). The objectivity of experts and expert bodies is guaranteed by a "trust in numbers," and the ongoing scrutiny of interested individuals and groups. Finally, as Jasanoff points out, this system (of credibility, authority, expertise, etc.) assumes that disclosure and transparency are *possible*, and that people have the will, the means, and the competence to evaluate the claims and proofs presented to them" (Jasanoff, 2005, p. 263).

In the UK, on the other had, issues of trust, accountability, expertise, and credibility are connected to what Jasanoff describes as "traditional British conceptions of the public servant: as persons of proven standing whose right to participate in knowledge-making for the state could not be seriously questioned" (Jasanoff, 2005, p. 261) because it is assumed that civil servants will act in the public interest (individual civil servants achieve standing "through a demonstrated record of service to society" (2005, p. 268)). While "trust in numbers" plays a role, Jasanoff argues that, "On the whole, objective knowledge is sought in Britain through consultation among persons whose capacity to discern the truth is regarded as privileged. Though British expert advisors can and do represent social interests to some extent, ultimately it is the excellence of each individual's personal discernment – the capacity to see distinctions that matter – that ensures something recognized as objectivity" (p. 266) … It is as if the expert's function is to discern the public's needs and to define the public good as much as it to provide appropriate technical knowledge and skills for resolving the matter at hand" (p. 268).

How do these differences in civic epistemology relate to the differences in efforts to "train" citizens to act appropriately in relation to science and technology? In the US, the civic epistemology allows for multiple opportunities of citizen participation in scientific and technical decision-making processes. Thus, training citizens to participate in *processes* makes sense as the goal of scientific literacy education. In the UK, however, the opportunities for citizen participation in scientific and technical decision-making practices did not exist to the same extent, at least in the 1980s and 1990s. Thus, training citizens in processes is not as important – instead, the goal is to maintain trust in the institutions that are making the decisions.

The danger of the US science education reforms is not that they focus on process, but rather that they constrain what counts as appropriate processes via a scientific fundamentalism, in which scientific knowledge and processes are privileged over all other forms of knowledge and processes. Thus, the ways in which science education is positioned as a site of training for 'appropriate' and 'enlightened' citizenship can be read as a large-scale "body project" reminiscent of what Foucault (1975/1995) describes as the third phase of discipline in the history of crime and punishment: "the body subjected to training," disciplined by forces aimed not at the body, but at the soul (1975/1995, p. 131). Foucault argues that the construction of this 'docile body' within the prison system is representative of the construction of normalcy and docility within the public-at-large, and that his book should serve as "a historical background to various studies of the power of normalization and the formation of knowledge in modern society" (1975/1995, p. 308). The rationally-trained, scientifically-minded citizen becomes defined as the normative position, or discipline, for members of the non-scientist public – creating the conditions of acquiescent democracy. Through the continual measurement and quantification of scientific literacy and the demarcation of citizens into categories of 'literate' and 'illiterate', the concerned public member can actually monitor his or herself against the established standard – thus, fulfilling Foucault's analysis, that at this stage of discipline power can be understood as being both "visible and unverifiable" (1975/1995, p. 201), inducing continual self-monitoring and self-observation.

This sharp 'quantifiable' distinction between the scientifically literate and illiterate has two additional effects: 1) making the public more legible – and therefore possibly more controllable – in a time of increasingly internal and external instability, and 2) creating a scientific under-class. First, on legibility: James Scott (1998) uses the concept of legibility to discuss the production and maintenance of the modern state. Legibility refers not to an accurate representation of the area (or persons) under examination, but rather to a rendering of the subject under study in a way that allows it to be managed most efficiently.

> Certain forms of knowledge and control require a narrowing of vision. The great advantage of such tunnel vision is that it brings into sharp focus certain limited aspects of an otherwise far more complex and unwieldy reality. This very simplification, in turn, makes the phenomenon at the center of the field of vision more legible and hence more susceptible to careful measurement and calculation. Combined with similar observations, an overall, aggregate, synoptic view of a

> selective reality is achieved, making possible a high degree of schematic knowledge, control, and manipulation (Scott, 1998, p. 11).

What Scott outlines is a process of coproduction (Jasanoff & Wynne, 1998): "What is distinctive about this logic … is the narrowness of its field of vision, the degree of elaboration to which it can be subjected, and above all … the degree to which it allow[s] the state to impose that logic on the very reality that was observed" (Jasanoff, 1998, pp. 13-14).

We know from Foucault's earlier work on ordering (1966/1970) that classification, itself, has a politics. Scott's case studies show that classification, in fact, can create realities based on its own reiterative categorization. Legibility – or radical simplification – according to Scott, provides the advantage of standardization, which allows for ease of observation and supervision from a centralized position of authority. The categories, themselves, become more important than the attributes they are said to capture. This framework for making sense of the ways in which the public anxiety of scientific literacy is represented in the dominant discourses forces our attention beyond the goal of training citizens to participate in a particular type of acquiescent democracy to the political meanings of being labeled scientifically illiterate. As indicated above, this demarcation creates a scientific underclass who cannot be trusted to participate appropriately in public and private decision-making. So, on the one hand, the aim of the persons participating in the public anxiety about scientific literacy *is* to actively construct scientifically and technically savvy citizens.

On the other hand, however, these programs construct a scientific and technical underclass by regularizing and compartmentalizing the non-scientist public into category (a) savvy or (b) ignorant. In addition to making the public legible through this act of organization, this labeling, perhaps paradoxically, supports the continued decision-making by scientific and technical experts until a time in which members of the public are responsible enough to handle this on their own.

Both categories, then, of bodies of the public that were identified and produced in the emergence and expansion of the public anxiety about scientific literacy – not just those who are or become scientifically literate – work to the benefit of state stability. That is, both ignorance (illiteracy) and this certain type of scientific expertise (literacy) can be read as active constructions of different types of 'docile bodies'. The pervasiveness of these categories serves to support the authority of science and the state because those recognized as scientifically literate are expected to provide support for scientific and technical development, whereas critics of science and technology or of the state can be labeled scientifically illiterate thus undercutting their authority to speak.

CONCLUSION

This chapter has explored the social, political, and institutional history of the current US national science education standards to identify why "science for all" matters to science educators and to the state. Today's emphasis on "science for all" emerged in response to perceived internal threats to the nation by "citizens behaving badly" – that is, social movements that questioned the authority of science and the state. The solution enacted within the standards offers a model of scientifically literate citizenship predicated on a model of acquiescent democracy in which non-scientists must actively participate in the privileging of scientific knowledge in all personal and public decision-making practices. This model of citizenship silences those who question the authority of science and the state by positioning them as scientifically illiterate, irrational and inappropriate – thus negating their ability to speak. Appropriate citizens, on the other hand, support the authority of science and the state and are thus offer a different type of silence. This dominant model of scientifically literate citizenship is why "science for all" must matter to educators committed to social justice – both inside and outside of science education.

CHAPTER 3: FEMINIST AND EQUITY ORIENTED INTERVENTIONS WITHIN SCIENCE EDUCATION

INTRODUCTION

According to the US national science education standards, the primary project of K-12 science education is training (future) non-scientists in the practice of scientifically literate citizenship. The previous chapter described the emergence and enactment of the dominant model of scientifically literate citizenship today by exploring the social, political, and institutional history of the current US national science education standards. The model of scientifically literate citizenship found in the standards aims to train (future) non-scientists to acquiesce to the authority of science and the state by actively demarcating science from non-science, experts from non-experts, and the rational from the irrational so that scientific knowledge is privileged in all personal and public decision-making practices.

This framework for the science education of non-scientists dominates the research and practice of science education today. Michalinos Zembylas (2005) describes this as an 'egalitarian' perspective that "claims that all citizens have the right and the responsibility to become scientifically literate" (Zembyals, 2005, p. 710) so that they "will act as informed, responsible citizens when confronted with … [socioscientific] issues" (p. 711). Troy Sadler's (2004) review of efforts within science education to train future citizens in informal reasoning likewise argues for the "inclusion of socioscientific issues in science classrooms" in order to develop "a responsible citizenry capable of applying scientific knowledge and habits of mind" (Sadler, 2004, p. 514; see also Driver, Newton, & Osborne, 2000; Kolstø, 2001; Zeidler, 1984). Current funding opportunities by the US National Science Foundation also affirm the continued dominance of this particular model of scientific literacy. The NSF Directorate for Education and Human Resources lists as one of its four primary goals the objective of increasing the "technological and scientific literacy of all U.S. citizens and residents so that they can participate responsibly in an increasingly technological society and acquire knowledge of science, technology, engineering, and mathematics that is appropriate to the development of workforce skills and life-long career opportunities" (NSF, 2006).

Today, many proponents of this model of scientifically literate citizenship have adopted the language of 'deliberative democracy', 'public engagement with science', and/or 'dialogic teaching' (Alexander, 2004; House of Lords, 2000; US Congress, 2003; see also: Driver, Newton & Osborne, 2000; Millar and Osborne, 1998; Newton, Driver & Osborne, 1999; Osborne, 2002). However, the assumption remains, in this 'deliberative turn', that non-scientists must adopt the processes of scientific thinking to participate appropriately within personal and public decision-making contexts. As Mark Elam and Margaretta Bertilsson (2003, p. 243) write, "By valuing rationality, reserve, selflessness and powers of argumentation, deliberative democracy is a democratic politics played out on scientists' home turf" (Elam & Bertilsson, 2003, p. 242) and boundaries "between experts and lay people; between rationality and irrationality; between producers and users of new technology" remain. This deliberative model of democracy has a

> two-fold identity: working not only to secure a new democratic face for science in society, but also to bring new standards of reasoning and argumentation from science to public life. Just as passion and outrage were necessarily absent from science according to the traditional Enlightenment model of science and society relations, so they can end up being rendered alien by the alliance of PES [public engagement with science] with deliberative democracy. In the latter context, passion and outrage become not only threats to Truth, but also to the achievement of a Fair and Just scientific democracy (Elam and Bertilsson, 2003, pp. 243-244).

Public participation via this ‘deliberative turn’ thus remains limited to spaces and modes and practices created and sanctioned by the scientific and governmental communities. The assumptions of acquiescent democracy remain unchallenged – to participate, non-scientists must still actively acquiesce to the authority of science and the state (see also Irwin, 2001; Wilsdon & Willis, 2004; Wynne, 2005).

This dominant model of scientifically literate citizenship is why “science for all” must matter to educators committed to social justice. However, I recognize that a logical question on the part of social justice educators outside of science education is, “Why do *we* have to intervene in this model of scientifically literate citizenship? Why can’t we rely, instead, on social justice educators *within* science education to undertake these needed interventions? How have social justice educators within science education changed the field?” The answer to these questions is in two parts. First, challenging the construction of scientifically literate citizenship has not been the primary goal of social justice interventions within science education. Instead, these interventions within science education have focused primarily on making science and science education more inclusive – that is, bringing girls and other underrepresented or underachieving groups *into* science. Second, these interventions naturalize alternative relationships between scientific knowledge and the non-scientist (whether or not the non-scientist citizen is conceptualized implicitly or explicitly). However, the alternative models of non-scientist citizenship that have emerged within science education pose risks of their own. It is therefore necessary to ask, not only, have feminist and equity-oriented interventions changed science education, but whether these new relationships offer alternatives to the dominant model of scientifically literate citizenship with which we can live.

THREE WAVES IN FEMINIST AND EQUITY-ORIENTED INTERVENTIONS IN SCIENCE EDUCATION

Angela Calabrese Barton (1998) identifies three different waves of feminist interventions within science education.

- First Wave Feminism in Science Education: Issues of Equity
- Second Wave Feminism in Science Education: Gender-Inclusive Science
- Third Wave Feminism in Science Education: Situating Knowing and Learning (Barton, 1998, pp. 1-19)

As is the case with feminism more broadly, these 'waves' overlap, intersect, and continue to function simultaneously today. Indeed, some feminist and equity-oriented science educators appear to engage simultaneously in all three projects. However, the wave structure is useful in making visible the differences in the three projects. Each of the waves of feminist and equity-oriented interventions within science education that Barton identifies focuses on making science more 'inclusive' for all – though the meaning and goal of 'inclusivity' is conceptualized differently depending upon the focus of the interventionist project.[1] In each case, however, the focus is on increasing access to science by underrepresented and marginalized students.[2] Michalinos Zembylas (2005) describes these feminist

[1] Today, a "fourth wave" of feminist and equity-oriented interventions may be emerging within science education, in which scientific literacy is understood as an attribute of communities rather than individuals. In this framework, "science is not [understood as] a single normative framework for rationality but merely one of many resources that people can drawn on in everyday collective decision-making processes" (Roth & Barton, 2004, p. 158) as they engage in the struggle to create a more just and equitable world. The possibilities provided by this "fourth wave" are discussed in Chapter 5.

[2] When feminist and equity-oriented science educators have discussed how race/ethnicity functions in the United States, their discussions have been limited, until very recently, to Black/African American students or to 'indigenous science'. Even today, discussions of Latino/a, Asian, and students of other races or ethnicities have primarily been limited to research on English Language Learners, first-generation college students/class, recent immigrant students, and/or how gender discourses are shaped by race/ethnicity. I recognize that in this chapter – which maps existing feminist and equity interventions in science education – I reproduce this "black/white" paradigm for discussing race/ethnicity (Hurtado, 2006). Likewise, following the history of these interventions, I reproduce the dominance of research on sex/gender in science education. In this research, when race, class, and other social differences are discussed, they are for the most part 'added' to sex/gender analyses. The ways in which this 'supplemental' approach to equity discussions constrains this research (Hurtado, 2006) is not discussed here.

and equity-oriented interventions within science education as offering a "critical perspective" that seeks "to examine the power relations and inequities embedded in science education" and offer, as an alternative, "science teaching and learning practices that empower children, build solidarity, and initiate change—an emphasis on 'science education for social justice'" (Zembylas, 2005, p. 710).

What strategies have feminist and equity-oriented science educators used to support their interventions? Each of the 'waves' of feminist and equity-oriented research and practice has used dominant discourses within the field of science education (such as 'science for all', the 'nature of science', and 'science for citizenship') as entry-points to the broader science education community and then sought to redefine these terms to better meet their objectives.[3] In this way, feminist and equity-oriented educators have positioned themselves both inside and outside science education by both participating in and simultaneously resisting the terms of the dominant discourse. Thus, mapping these efforts complicates what we know about science education today, offering a new understanding of science education hegemony (and what it means to operate within it), which can be better elucidated by turning to Saul Halfon's analysis of international population policies. Halfon reconceptualizes the appearance of consensus (in this case, to the concepts of 'science for all', the 'nature of science', and 'science for citizenship') from 'unity' to 'structured *dis*unity (Halfon, forthcoming). As Halfon proposes, consensus functions not because of "cognitive, strategic, nor practical agreement on basic facts, assumptions, activities, or goals," but rather consensus represents a "commitment to and enrolment in a common socio-technical network …which allows various

[3] For example: "This article explores the way in which scientific literacy has been defined, justified, and operationalized in current proposals for science education reform. We argue that, although the vision of scientific literacy reflected in the reform proposals is broad, progressive, and inclusive, it is being implemented in narrow and conventional ways" (Eisenhart, Finkel & Marion, 1996).

actors to act 'as if' they were all doing and thinking the same thing (that is, 'as if' there were unity)" (Halfon, forthcoming, p. 2).

Halfon's work builds on the concepts of 'boundary objects' (Bowker & Star, 1999) and 'standardized packages' (Fujimura, 1992), as developed within Social Worlds theory. Boundary objects,

> are those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. Boundary objects are thus both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual-site use. These objects may be abstract or concrete. … Boundary objects have different meanings in different worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting communities (Bowker & Star, 1999, p. 297; see also Star & Griesmer, 1989).

Fujimura (1992) developed the concept of a 'standardized package' to "define a conceptual and technical work space which is less abstract, less ill-structured, less ambiguous, and less amorphous" than boundary objects. Through this lens, concepts like 'science for all', the 'nature of science', and 'science for citizenship', found within the national science education standards and current practice in mainstream science education, can be understood as boundary objects that allow feminist and equity-oriented science educators to communicate with the mainstream science education community. However, as will be discussed in the conclusion of this chapter, this strategy of participating in and simultaneously resisting dominant discourses through this 'boundary work' simultaneously constrains the types of interventions that can take place – identifying weaknesses in "consensus as structured *dis*unity" as a strategy for social justice.

As a further clarification: in this chapter, I am primarily interested in describing and assessing the strategies and impact of feminist and equity-oriented interventions that directly engage dominant assumptions within the field of science education that have achieved visibility within the mainstream of the field. Thus, I have chosen to focus on research published within journals recognized by the mainstream science education community as sites of communication about the theory and practice of science education. The three primary journals of science education research are the *Journal of Research in Science Teaching*, *Science Education*, and the *International Journal of Science Education* (formerly the *European Journal of Science Education*).[4] I understand these journals to function as gatekeepers for the broader science education community, policing – through a variety of mechanisms including the peer review system, editorial policies, and so forth – what "counts" as science education research.

However, feminist and equity-oriented research did not begin to appear in these three journals until the mid-to-late 1980s. Few articles in these journals in the 1970s and early 1980s addressed gender or issues equity in any way. Those that did, as feminist science educator Dale Baker (2002) describes, "used sex as a correlate of some kind of cognitive ability deemed critical to success in science" (Baker, 2002, p. 660). As Baker continues,

> These studies were either psychological in orientation and used White male performance as the benchmark, or lacked explicit theoretical frameworks. However, they did share an implicit framework. They were conducted under what I call the "My Fair Lady" framework, or "Why can't a woman be more like a man?" When there were differences or correlates, the White male model was the right model. (Baker, 2002, p. 660).

[4] These three journals were identified as primary sites in three ways: 1) rankings in the Social Science Citations Index; 2) interviews with feminist and equity-oriented science education researchers; and 3) participant observation within the field of science education.

However, as I briefly describe in the next section, much feminist and equity-oriented attention was directed at science and science education throughout the 1970s and 1980s prior to the emergence of feminist and equity-oriented work within mainstream science education journals. These feminist and equity-oriented projects outside of science education then informed the subject matter and methodologies of feminist and equity-oriented work that gained entry to mainstream science education a decade later.

FEMINIST CRITIQUES OF SCIENCE AND SCIENCE EDUCATION: 1970-1985

In 1986, Sandra Harding identified five different types of feminist projects on women, gender, and science that had occurred in the previous decade (all of which occurred outside the three gatekeeper journals of the mainstream science education community). As she described it,

> Since the mid-1970s, feminist criticisms of science have evolved from a reformist to a revolutionary position, from analyses that offered the possibility of improving the science we have, to calls for a transformation in the very foundations both of science and of the cultures that accord it value. We began by asking, "What is to be done about the situation of women in science?" – the "women question" in science. Now feminists often pose a different question: "Is it possible to use for emancipatory ends sciences that are apparently so intimately involved in Western, bourgeois, and masculine projects?" – the "science question" in feminism (Harding, 1986, p. 9).

Below, borrowing from Harding's classifications, I provide a brief overview of these feminist and equity-oriented interventions occurring outside the mainstream of science education in the 1970s and 1980s.[5]

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[5] Harding's (1986) categories of feminist critiques of science are: 1) "equity studies"; 2) "uses and abuses of biology, the social sciences, and their technologies"; 3) questions regarding the "possible existence of any pure science at all" due to the inherent value-ladenness of science and the underdetermination of scientific theory; 4) "related techniques of literary criticism, historical interpretation, and psychoanalysis have been used to 'read science as a text' in order to reveal social meanings"; and 5) "epistemological inquiries" that have

Equal Opportunity for Women and Minorities in Science and Science Education, Part I: Formal Barriers

The first phase of feminist and equity-oriented work in science and science education was to remove formal barriers to participation in science by women and members of minority groups. This new legal environment of equal opportunity began to emerge in the 1960s. Throughout this time period, new laws, executive orders, and court decisions (including Title VI and VII of the Civil Rights Act of 1964, the Equal Opportunity Act of 1972, and Title IX of the Educational Amendments of 1972) created a new national context for women and minorities in science education and STEM employment. While organizations like the National Science Foundation were initially resistant to supporting 'affirmative action' in science and science education, Juan Lucena (2005) describes how women and minority groups during this time period moved from asserting their right to equal opportunities (as mandated by the new laws) to strategically arguing that increasing access to science education and the STEM workforce for women and minorities was not only good for these underrepresented groups, "but it was also good for science" (Lucena, 2005, p. 76). For instance, during the 1970s, at a time in which the United States was troubled by domestic problems related to the inner cities, Mark Miles Fisher, Executive Secretary of the National Association for Equal Opportunity in Higher Education, argued that including Black Americans in science was a "matter of national survival" because Black people had "intrinsic knowledge of Black America, specifically the inner cities, which whites lacked" (Lucena, 2005, p. 71). Fisher's arguments led to an increase in the NSF budget directed towards historically black universities and colleges (HBUCs) in 1974.

A similar strategy was employed by Shirley Malcolm and Janet Welsh Brown, both of the Office of Opportunities in Science of the American Association for the Advancement Science

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"laid the basis for an alternative understanding of how beliefs are grounded in social experiences, and of what kind of experience should ground the beliefs we honor as knowledge" including feminist empiricism, feminist standpoint theory, and feminist postmodernism (21-28).

(AAAS). For example, in testimony to the US House Committee on Appropriations in 1976, Janet Welsh Brown argued that, "the nation pays a very high cost for this inequality" (US House Committee on Appropriations 1976, p. 1851; cited in Lucena, 2005, p. 77). As she continued,

> The third cost is to science itself. The so-called "search for truth" and the scientific method require that ideas and values and assumptions be subjected to constant challenges and examination. I believe that diversity of cultural and other backgrounds helps assure that challenge and that diversity is necessary for good science. There is much in our accepted and unquestioned knowledge that is based on false assumptions and imperfect of incomplete research … My hypothesis is that if there has been a healthier mix of women and minorities in the world of scientific research, more of those values and assumptions would have been questioned earlier (US House Committee on Appropriations 1976, p. 1851; cited in Lucena, 2005, p. 77)

During this time period, women and minority groups started using statistics from the Scientific Manpower Studies conducted for the NSF to document inequities in participation. In addition to employing these statistics in testimony before Congress, statistical data on the underrepresentation of women and minorities was also made public in publications like *Science* (Vetter, 1978; Albin, 1979; Branscomb, 1979); *Impact of Science on Society* (Ghosh, 1975; Shapley, 1975); *Trends in Biochemical Sciences* (Baltscheffsky, 1976); *Applied Optics* (Bautz ,1977); *Communications of the ACM* (Montanelli & Mamrak 1976; Mamrak & Montanelli, 1978); *American Biology Teacher* (Strauss, 1978); *USA Today* (Jones, 1978); and *Nature* (Anon, 1979). Lucena suggests that the use of this statistical data by women and minority groups in the 1970s led to the Science and Technology Equal Opportunity Act of 1980, "in which Congress directed the NSF to begin publishing data on women and minority representation in science and engineering" (Lucena, 2005, p. 76).

In the 1980s, women and minority groups were again able to strengthen their argument for the right to equal opportunities in science and science education by positioning their increased participation as the solution to the "manpower shortage" that resulted from a new external threat to the nation: economic competitiveness with Japan. As Lucena describes, a new technology of representation emerged in this context – "the pipeline." The pipeline metaphor highlighted "women and minorities as significant categories of economic competitiveness" (Lucena, 2005, p. 122). In 1987, the Task Force on Women, Minorities and the Handicapped in Science and Engineering became law and was charged "to examine the current status of women, minorities, and the handicapped in science and engineering and to coordinate existing federal programs to promote their education and employment in these fields" (Lucena, 2005, p. 114). This task force produced a report entitled, *Changing America: The New Face of Science and Engineering*, which argued that "the representation of underrepresented groups in science and engineering [should be] everybody's business, and a 'goal for the American Nation'" (Lucena, 2005, p. 115).

Equal Opportunity for Women and Minorities in Science and Science Education, Part II: Informal Barriers

In addition to highlighting the importance of women and minorities to science and the nation, the "pipeline metaphor" also made visible the multiple stages at which women and minorities "leak" from the pipeline to the nation, as a whole. Beginning in the 1970s, feminists had begun to identify the informal barriers that continued to limit the participation of women and minority groups in science – "the leaks," so to speak. For instance, researchers such as Harriet Zuckerman (Zuckerman & Cole, 1975), Jonathan Cole (Zuckerman & Cole, 1975; Cole, 1979, 1981), Janice Law Trecker (1974), and Alison Kelly (1979, 1981, 1982) identified the ways in which these informal barriers were embedded in the social structure of science, science education, and society, leading to what Henry

Etzkowitz, et al, (2000) have recently described as a "cumulative disadvantage" for girls and women in science, in which girls and women are deflected away from science in a series of "critical transitions" that include the development of gender roles in children, the "weed-out system" facing undergraduate science and engineering majors, advisor relationships in the graduate and postgraduate career path, and scientific organization at the faculty level, including the hiring and tenure process, as well as issues like child care access. While like much of the feminist literature at this time, many feminist analyses of the status of women in science did not pay attention to the intersection of race and gender. However, some research did focus specifically on the double burden faced by women of color in science (Malcolm, Hall & Brown, 1976; Kahle, 1982; Cummings, 1984).

This sociological research was supplemented in two ways. First, by the publication of personal accounts of the barriers faced by women and people of color in science, including Aimee Sands (1986) interview with Evelyn Hammonds, entitled "Never Meant to Survive: A Black Women's Journey," Naomi Weisstein's (1977) "'How can a little girl like you teach a great big class of men?' the Chairman Said, and Other Adventures of a Women in Science," Evelyn Fox Keller's (1977) "The Anomaly of a Woman in Physics," and Vivian Gornick's (1983) publication of descriptive accounts of numerous women's experiences of discrimination in the workplace. Biographies of 20th century women scientists like Barbara McClintock (Keller, 1983) and Rosalind Franklin (Sayre, 1975) also described the "problems for women in science." Second, the publication of histories of women in science both 'recovered' past woman scientists previously invisible to the historical record (Kohlstedt, 1978a, 1978b; Alic, 1986) and described the long history of formal and informal barriers to women's participation in science (Rossiter 1974, 1980, 1982; Schiebinger, 1989). Margaret Rossiter's work, in particular, offered a powerful lens for feminists via her identification of two simultaneous types of segregation experienced by women in science: hierarchical (in which women occupy less prestigious jobs such as 'lab technician' rather than 'scientist') and territorial (in which women cluster in certain scientific fields in higher education and the STEM workforce).

Androcentric (and Other) Bias in the Production & Use of Scientific Knowledge

The second feminist critique of science during this time period identified androcentric bias in both the production and use of scientific knowledge. Attention to the ways in which science has been used "in the service of sexist, racist, homophobic, and classist social projects" (Harding, 1986, p. 21) grew out the Women's Health Movement that emerged in the 1960s and 1970s (e.g., Boston Women's Health Collective 1973; see Morgen, 2002). Thus, much of this work focused on the use and production of biological science and medical knowledge (e.g., Tobach and Rosoff, 1978, 1979, 1981, 1984; Hubbard, Henifin & Fried, 1979; Fee, 1983; Jaggar, 1983; Bleir, 1984) and the ways in which past and contemporary scientific knowledge naturalized the oppression of women. For instance, the work of Barbara Ehrenreich and Deidre English (1972, 1973, 1978) examined the "sexual politics" of sickness and childbirth. New reproductive technologies, including the birth control pill and *in vitro* fertilization, were also a primary focus (e.g. Holmes, 1981; Arditti, Duelli-Klein & Minden, 1984). Historical examinations by Elizabeth Fee (1983) and Stephen Jay Gould (1981) examined how the science of craniology was both shaped by sexist and racist stereotypes and then used to maintain systems of oppression for women and persons of African descent. Joy Ladner (1971) and Nancy Stepan (1982, 1986) described the ways in which the science of race, more broadly, constructed non-white bodies as deviant. James Jones (1981) account of the Tuskegee syphilis experiments documented the abuse of Black people as sites of scientific research.

Other feminist work showed how underlying assumptions about sex and gender shaped entire fields of scientific research, including primatology and evolutionary studies (Haraway, 1978;

Hubbard, 1981; Hrdy, 1981 1986), cell biology (Fausto-Sterling, 1981; Biology and Gender Study Group, 1988), and neuroendocrinology (Longino & Doell, 1983). According to this research, the positioning of earlier (predominantly male) scientists within a sexist society, which naturalized the dominant role of men and the oppression of women, provided the lenses through which these scientists then "saw" nature, leading them to "miss" or "misread" evidence and data. Thus, for instance, typical evolutionary studies done by men stressed the critical role of "man-the-hunter" in human evolution, whereas as women or feminist scientists examining the same data were able to "see differently," putting forth theories stressing the critical role of "woman-the-gatherer" in evolutionary narratives. The ways in which a "gendered lens" shaped the production of past scientific knowledge was also emphasized by feminist researchers such as Carolyn Merchant (1980), Evelyn Fox Keller (1985), Ludmilla Jordanova (1980), and Emily Martin (1987) who examined sexist metaphors in the birth and continuing practice of modern science.

Feminist Epistemologies

Feminist critiques of science that focused on androcentric bias in the production and use of scientific knowledge, as well as work documenting the history and contemporary status of women in science, raised central epistemological questions regarding the production of scientific knowledge. For instance, "Is objectivity or value-free science possible?"; "Is there a feminist methodology of science?"; and "Do women scientists necessarily do science differently?" These epistemological inquiries "imply a relation between knowing and being, between epistemology and metaphysics, that is an alternative to the dominant epistemologies developed to justify science's modes of knowledge-seeking and ways of being in the world" (Harding, 1986, p. 24). In 1986, Harding identified three different projects in feminist epistemology of the sciences: feminist empiricism, feminist standpoint theory, and feminist postmodernism.

In this work, different approaches can be distinguished by asking whether the approach understands identified androcentric biases in the production of scientific knowledge as "bad science" or "science as usual." Feminist empiricists during this time period, for instance, argued that androcentric biases are examples of "bad science" that must (and can) be weeded out as "the covers and blinders that obscure knowledge and observation" (Millman and Kanter, 1975, p. vii; cited in Harding, 1986, p. 24) are removed via "stricter adherence to the existing methodological norms of scientific inquiry" (Harding, 1986, p. 24). Feminist standpoint theorists and feminist postmodernists, on the other hand, understand androcentric bias as "science as usual."

Feminist standpoint theorists at this time can be divided into two camps. First, some feminist standpoint theorists argued that there are "women's ways of knowing" – which include, for instance, an ethic of care and preference for holism over reductionism (Gilligan, 1982; Rose, 1983; Rosser, 1988). Thus, intervening in "science as usual" involves privileging "women's ways of knowing" over "men's ways of knowing" to produce woman-friendly science. Other feminist standpoint theorists adopted a (somewhat) less essentialist position by arguing that women's ability to "see better" than men is the result of their different positioning within society. That is, the subjugation of women in society "provides the possibility of more complete and less perverse understandings" (Harding, 1986, p. 26; see Hartsock, 1983; Flax, 1983; Smith, 1974, 1977, 1979, 1981). Thus, grounding the production of scientific knowledge in the experiences of the subjugated or marginalized is understood to provide a better, more objective science – what Harding will later refer to as "strong objectivity." This science is not value-free, but instead driven by the valuing of women's (and others) needs, experiences, and perspectives.

The third approach to feminist epistemology during this time period is what Harding identifies as feminist postmodernism. Feminist postmodernist approaches to epistemology were, in part, a response to feminist empiricism and feminist standpoint theory. Feminist postmodernists argued that the development of "one, true, feminist story of reality" is an impossibility due to both the differences amongst women and their experiences (by race, class, sexuality, etc.) and the fluidity – rather than stability – of identity (Haraway, 1985; see also Fee, 1981, 1982; Lloyd, 1984). As discussed in Chapter 1 (Introduction), Donna Haraway (1985) identified the problem facing feminists as "how to have *simultaneously* an account of radical historical contingency for all knowledge claims and knowing subjects, a critical practice for recognizing our own 'semiotic technologies' for making meanings, *and* a no-nonsense commitment to faithful accounts of a 'real' world, one that can be partially shared and friendly to earth-wide projects of finite freedom, adequate material abundance, modest meaning in suffering, and limited happiness" (Haraway, 1985, p. 187). "From this perspective, feminist claims are more plausible only insofar as they are grounded in a solidarity between these modern fractured identities and between the politics they create" (Harding, 1986, p. 28).

Since the mid-1980s, all three projects in feminist epistemology have become more nuanced, and the boundaries between approaches have sometimes blurred (for instance, Helen Longino's (1990, 2005) contextual empiricism can be read as taking feminist standpoint and feminist postmodern epistemologies seriously in her development of a new feminist empiricism). Feminist critiques of science, in general, have likewise expanded to focus on other fields such as engineering and physics. However, I have chosen to stop my story of feminist critiques of science outside of science education here – roughly, in the mid-1980s – as this is the time during which feminist and equity-oriented science education researchers first began publishing in mainstream science education journals. The next section identifies the strategies employed by these researchers to gain entry to the field – to move from margin to center.

FEMINIST AND EQUITY-ORIENTED INTERVENTIONS WITHIN SCIENCE EDUCATION

As described in the previous chapter, 'science for all' emerged as the primary goal of US science education in the 1980s – an emphasis that was later solidified in the development of new national science education standards and reform documents in the late 1980s and 1990s (AAAS, 1989, 1993, 1997; NSTA 1992; NRC 1996). These standards situated science education as a primary site for the training of appropriate citizens, connecting scientific literacy to citizenship in ways that privileged thinking like a scientist in all personal and public decision-making practices. At the time of national science education reforms, feminist and equity-oriented interventions within science education were able to enter the mainstream (that is, appear in the gatekeeper science education journals), by using 'science for all', the 'nature of science', and 'science for citizenship' as 'boundary objects' or entry-points to the broader field. Each wave then sought to redefine the political meanings of the 'boundary objects' to make science more inclusive. Each of the three waves of feminist and equity-oriented interventions described themselves as changing science education to create opportunities to truly include all students in 'science for all'. In this way, feminist and equity-oriented educators have positioned themselves both inside and outside science education by both participating in and simultaneously resisting the terms of the dominant discourse.

Barton's Waves (1998)	**'Entry-Points'**	**Primary Site of Change**
First Wave: Issues of Equity	'Science for All'	Social Structure of Science Education
Second-Wave: Gender-Inclusive Science	'Science for All' 'Nature of Science'	Scientific Knowledge
Third-Wave: Situated Knowing and Learning	'Science for All' 'Nature of Science' 'Science for Citizenship'	Uses of Science

Table 3: Feminist and Equity Oriented Interventions Within Science Education

First Wave: Issues of Equity

The first wave of feminist and equity-oriented interventions within science education first appeared in the mid-to-late 1980s, and continues today. The primary focus of this wave is to make science more inclusive to girls and under-represented minorities by intervening in the informal barriers that limit participation in science education and science – that is, the myriad ways in which girls and students of color are deflected away from science via the social structure of science, science education, and society (such as gender stereotypes about who can be a scientists, pedagogical and testing practices that are biased against girls and people of color, and so forth). Inclusivity, for the first wave, means increasing the number of girls and under-represented minorities who achieve highly and continue to pursue science education. The first wave provides a critique of the mainstream science education community's discussion and enactment of "science for all," which focuses on "the ways in which girls and minorities are 'inferior'" and provides 'compensatory' and 'assimilationist' strategies (Eisenhart, Finkel & Marion, 1996; Lee, 1999) to address perceived deficits in underrepresented and underachieving individuals who must be trained to adopt the learning practices of the dominant culture so that they, too, may achieve in science. Instead, the first wave turns attention to "the kinds of structural and institutional constraints that posed barriers to successful participation in science by girls and minorities (Brickhouse, 1994)" (Barton, 1998, p. 3; see also Rodriguez, 1998).

The first special issue on Gender and Science Education appeared in the *International Journal of Science Education* in 1987. Edited by Alison Kelly (who had a previously published work on girls and science education outside of the gatekeeper journals), this issue included articles on the history of gender and science (Koblitz, 1987; Outram, 1987), course development and support programs for girls and women (Carter, 1987; Newton & Williamson, 1987; Verne, 1987), indigenous knowledge and girls science education (Amara, 1987), science teacher attitudes towards boys and girls in science (Vanvoderen & Dijkstra, 1987), and the relationship between gender and science achievement (Haggerty, 1987). Other first wave research that appeared in the late 1980s and early 1990s focused on: the stereotypic images of scientists held by young people (Newton & Newton, 1992); how early childhood experiences such as toy-playing shaped girls' and boys' interest and ability in science education (Tracy, 1990; Fleer, 1990); girls' attitudes towards science (Kelly, 1986; Levin, Sabar & Libman, 1991; Jejede & Okebukola, 1992); the role of perceived ability or self-concept in the retention of girls in science (DeBoer, 1986; Baker, 1987); broader explorations of the reasons girls continue or discontinue in science (DeBoer, 1984; Jones & Wheatley, 1989; Campbell, 1991; Ndunda & Munby, 1991); the perpetuation of gender and racial stereotypes in science textbooks (Powell & Garcia, 1985; Bazler & Simonis, 1991; Potter & Rosser, 1992; Lieberman, Hampton, Littlefield & Hallead, 1992); the role of role models in the retention of girls in science (Smith & Erb, 1986); gender bias in testing (Linn, Debenedictis, Delucchi, Harris & Stage, 1987; Bateson & Parsonschatman, 1989; Zoller & Benchaim, 1990); gender biases behavior in teachers (Jones & Wheatley, 1989, 1990; Shepardson & Pizzini, 1992; Taber, 1992; Scantleburry & Kahle, 1993); the effect of pedagogical changes such as single-sex teaching and collaborative learning (Johnson,

Johnson, Scott & Ramolae, 1985; Hamilton, 1985; Staver & Halstead, 1985; Conwell, Griffin & Algozzine, 1993); and the outcome of programs to support 'gender-free' learning environments (Mason & Kahle, 1989; Trigwell, 1990; Sudweeks & Tolman, 1993).

The strategies employed by the first wave of feminist and equity-oriented science educators for making science more inclusive continue today. The National Science Foundation (NSF) and the American Association for University Women (AAUW), for instance, together "invested nearly $90 million to fund more than 400 projects specifically aimed at increasing the participation of girls and women in STEM fields" between 1993-2001 (AAUW 2004: iii). Within AAUW & NSF programs focused on science, the most popular strategies to make science more inclusive "included the use of mentors or role models, hands-on pedagogy, and field trips" (AAUW, 2004, p. 6). Race and class have received significantly less attention than gender in first wave feminist and equity-oriented interventions. However, race and class, as well as other types of difference (including English as a second language learners), are areas of increasing attention in science education more broadly, and first wave strategies for inclusivity focused on these groups can be found in multiple articles published between 2000-05, including: Grayson, 1996; Atwater, 2000; Brickhouse, Lowery & Schultz, 2000; Kahle, Meece & Scantlebury, 2000; Tobin, Roth & Zimmerman, 2001; Kurth, Anderson & Palincsar, 2002; Case & Jawitz, 2004; and Russell & Atwater, 2005. Parallel programs to those funded by the AAUW & NSF for girls now exist, like CSTEP (the Collegiate Science & Technology Entry Program), funded by the New York State Education Department, which provides resources "to increase the number of historically underrepresented students who enroll in and complete undergraduate or graduate programs leading to professional licensure or to careers in mathematics, science, technology (MST), and health related fields" by providing "academic enrichment and research experience in science, mathematics, and technology content areas" (CSTEP, 2005).[6][7]

Due to the continuing achievement and participation gaps for underrepresented minority groups in science education and the STEM workforce (as will be discussed in detail below), the importance of the first wave strategies for inclusivity cannot be underestimated. Robert Moses (2001), for instance, argues that math literacy, specifically access to and success in algebra is the site of the new struggle for civil rights. Because algebra functions as a "gatekeeper" to the college preparatory track within U.S. high schools, increasing access to algebra education at the middle school level increases access to college. This is especially important for students of color and poor students who are more likely to be "tracked low" by a tracking system that reinforces rather than challenges class and racial privilege. While the second and third wave efforts to redefine the nature of science to make scientific content more inclusive (as will be discussed below), are also part of the ongoing struggle for equality, understanding what counts as science within the dominant culture provides access to the "language of power" (Christensen, 2003; Delpit, 1995) as it exists today. Thus the need for first wave interventions, like Moses' Algebra Project – which aims to empower students and their families to *demand* algebra education by challenging the social structure of STEM education – cannot be underestimated.

Second-Wave: Gender-Inclusive Science

Within the gatekeeper science education journals, the second wave of feminist and equity-oriented interventions within science education began to appear in the 1990s. Like the first wave of feminist

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[6] http://www.highered.nysed.gov/kiap/COLLEGIATE/CSTEP%202004/introduction_to_cstep.htm

[7] The Minority Academic Opportunities Program (MAOP) at Virginia Tech is another example, as is the Upward Bound program, which targets low-income and first generation college students.

and equity-oriented interventions, the second wave employed 'science for all' as an entry-point to the mainstream science education community. Unlike the first wave, however, the second wave sought to make science education more inclusive by focusing, predominantly, on making scientific content knowledge, itself, more inclusive to girls and other under-represented and under-achieving groups in science and science education. Thus, the second wave began to question the "values and standards of science and science education" (Barton, 1998, p. 4) by turning attention to scientific knowledge production and ways of knowing, using mainstream attention to the 'nature of science' as a second entry-point for this interventionist project. Again, meaning of inclusivity for the second wave focused on increasing the number of women and other under-represented groups in science education and the STEM workforce.

As discussed in the previous chapter, the 'nature of science' plays a key role in mainstream science education in that exposure to the 'nature of science' and the 'scientific worldview' is understood to train all students to "think like scientists" in all personal and public decision-making practices, thus producing the dominant model of scientifically literate citizenship. The second wave of feminist and equity-oriented science education researchers seek to broaden the scope of the 'nature of science' to "explore multiple ways of knowing and doing science that are reflective of the social, historical, and political context in which science has been constructed and in which students learn science (Barton, 1995; Barton & Osborne, 1995; Brickhouse, 1994; Roychoudhury, Tippins & Nichols, 1993, 1995; WISE 1994, 1995)" (Barton 1998, p. 4). As Okhee Lee (1999) describes, these feminist and equity-oriented science educators questioned the "conservative orientation" of the new national science education standards because the standards do not "consider [the] diversity of students' language, culture, gender, and socioeconomic backgrounds as important because science is represented as universal knowledge" (Lee, 1999, np). Unlike the national science education standards which seek "to enable students to become members of the scientific community without changing existing science systems" (Lee, 1999, np), the second wave sought to change science, itself.

This shift to the nature of science by feminist and equity-oriented science educators emerged within the context of insights generated by feminist (and other) researchers in the sociology, philosophy, and history of science that identified the ways in which social and cultural values have shaped scientific knowledge production practices, and questioned whether value-free science and objectivity can exist (e.g., Keller, 1985; Harding, 1986, 1987, 1991; Longino, 1989, 1990). Most important for these feminist science educators, as Barton points out, were the ways in which masculinity was privileged within what counts as science and scientific ways of knowing, leading both to the marginalization of women and 'women's ways of knowing' as well as an instrumental understanding of the natural world. Feminist science educators employed these analyses "to understand science as a social construct to spark debate about ways of knowing science and the implications that this has for science for all" (Barton, 1998, p. 10; see also Barton & Osborne, 1995; Eisenhart, Finkel & Marion, 1996). Educators working in this area have expanded discussions about the nature of science and the processes of scientific knowledge production to incorporate marginalized ways of knowing and students' lived experiences into the curricula and challenge the narrowness of scientific vision – as Brickhouse (1994) describes, the separation of rationality from emotion and ideas from context.

The second wave of feminist and equity-oriented interventions within science education has proposed multiple changes to the institution of science education to make science more inclusive. Most visibly, the second wave called for the development of 'gender-inclusive' and 'multicultural-inclusive science curricula to make science more 'friendly' to girls and other underrepresented and under-achieving groups. Proposals for 'gender-inclusive' science is a response to the "epistemic differences between men and women from their standpoint in life" and the ways in which these differences provided "differential interaction with the nature of science, and hence their participation in the field" (Roychoudhury, Tippins & Nichols, 1995, p. 897). 'Gender inclusive' science has four characteristics:

> First, scientific knowledge is acknowledged as culturally and socially bound. Embedded within the gender-inclusive science curriculum is a study of the social context that has influenced the study of particular areas of science, and the effect of this context on the scientific ideas developed and accepted within the scientific community. Second, scientific knowledge is reflective of nature's holistic, interactive, and complex existence. Scientific models used in the classroom would "stress context rather than isolated traits and behaviours, interactive rather than linear relations, democratic rather than authoritarian models of order in both research and nature" (Harding 1991, 300). Third, the scientific contributions of women and minorities, including those who have not been formally recognized by the community of scientists, are incorporated into a historical analysis of scientific knowledge. … Fourth, science is practiced through multiple ways of knowing, including, but not limited to, "women's ways of knowing" such as collaboration, cooperation, and caring (Barton, 1998, p. 11).

Other science educators focused on the development of 'multicultural-inclusive' science education in a similar fashion. For instance, Derek Hodson (1993) argued that a science curriculum that only includes Western science does violence to students who do not share this cultural framework; William Stanley and Nancy Brickhouse (1994) argued that the nature of science taught in science education "should reflect a multicultural perspective on scientific knowledge" (Brickhouse, 1994, p. 387); and Masakata Ogawa (1995) asked, "Why should we teach Western modern science alone and other others' sciences?"

Many of these second-wave efforts to make science education more inclusive are predicated on essentialist assumptions about the ways in which "ways of knowing" are located within individuals and an oversimplification of non-Western science knowledge systems – criticisms that, in part, prompted what Barton identifies as the third wave of feminist and equity-oriented interventions. However, the second-wave powerfully articulates the need for science educators to recognize the values and experiences that students bring to school science, and how these differences shape students' abilities to engage with dominant understandings of science. While educational constructivism is part of the discourse of the mainstream science education community, second wave efforts attached questions of power and access to constructivist accounts, and moved the focus from individuals (as constructivism is normally conceptualized within science education) to society (see Atwater 1996). Second wave efforts also made visible the politics of scientific knowledge, 'nature of science', and school science content within the mainstream science education community.

Third Wave: Situated Knowing and Learning

The third wave of feminist and equity-oriented interventions within science education also first emerged in the 1990s. This third wave, which Barton (1998) describes as understanding "science education as situated knowing and learning," builds on the work of the first two waves of feminist and equity-oriented intervention. Like the first and second waves, the third wave seeks to make science more inclusive – to better meet the goal of 'science for all' (WISE, 1996; Hazelwood, 1996). Like the second wave, the third wave situates the 'nature of science' as a site of political contention (WISE, 1996; Roth, 1995). However, the third wave questions the essentialism and separatism in earlier feminist analyses and practices and emphasizes the need for reflexivity around issues of identity by paying attention to the intersections of race, class, and gender (Barton, 1998). Thus, gender and race continue to matter for third wave science educators, but this is not because of an assumption that there are particular ways of knowing innate to different sexes or races/ethnicities. Rather, gender and race matter because gender and racial differences intersect with differences in power and access, and these gendered and raced histories – both individual and social – have shaped experiences of learning and knowing leading to different learning styles.

Second, third wave feminist and equity-oriented science educators more explicitly situate science and science education in the broader social context and recognize that science education practice and research can either perpetuate or challenge the political realities in which they are embedded – that is, the social, economic, and political ideologies of the dominant culture (Shymansky & Kyle, 1992). Barton argues that third wave feminist science educators continue to focus on "understanding and questioning the nature of science," but also on identifying and challenging the role of scientific knowledge in everyday lives – i.e., "the connection between the production and use of scientific knowledge and authority" (Barton, 1998, p. 16), as well as the political and ethical responsibilities of science and of science education for the world (and it injustices) that exists today. This shift demands that science educators and students understand scientific knowledge production and education within a broader socio-political context, and recognize that "science teaching is political and activist" (WISE, 1996).

The third wave offers a different vision of inclusivity and what it means to teach science for social justice. Like the first and second waves of interventions, there is an assumption that increasing the number of women and other under-represented groups in science education and the STEM workforce is a project that feminist and equity-oriented science educators should pursue. However, additional attention is directed at positioning science as a tool for social justice for non-scientists by situating (future) non-scientists as simultaneously producers, critics, and consumers of scientific knowledge. Thus, the third wave offers a new model of 'science for citizenship' to challenge the dominant model of scientifically literate citizenship found in mainstream science education, using the mainstream focus on 'science for citizenship' as a third entry-point. For instance, Derek Hodson (1999, p. 12) argues that science education should "produce activists: people who will fight for what is right, good, and just; people who will work vigorously in the best interests of the biosphere." Obed Norman (1998, p. 365) concurs, arguing that science education should "equip our students with a degree of scientific literacy that will enable them to appreciate both the vast potential as well as the limitations of science [so that] our students can become effective and credible champions of a scientific enterprise committed to serve all humanity."

The third wave provides a new image of science: relevant science for social responsibility that comes from children's lives. It also provides a new image of a non-scientist citizen: an active participant in scientific and technical decision-making who can use relevant science as a tool to work towards social justice. For instance, Barton's work in after-school science programs with homeless urban youth primarily makes links between scientific knowledge production and lived experience to create opportunities to "co-opt science" at "individual, interactional, and structural levels" and create relevant science (like community garden projects) as a tool for social justice (Barton et al, 2003, p. 161). Wolf-Michael Roth's (Roth & Barton, 2004) work with "successful" and "unsuccessful" science students in the Pacific Northwest on water quality and other environmental projects – in which students conduct research relevant to their lives and present this research as part of community discussions on development, sustainability, and ecosystem preservation – also positions scientific knowledge as a tool for social justice and (future) non-scientists as producers of relevant scientific knowledge, as well as providing an example of what it means to do socially responsible and relevant science that meets community needs.

HAVE FEMININST AND EQUITY-ORIENTED INTERVENTIONS CHANGED SCIENCE EDUCATION?

In 1999, Londa Schiebinger asked, “Has feminism changed science?” A similar question can be asked here about the impact of feminist and equity-oriented interventions within science education. The challenges faced by feminist and equity-oriented science educators are multiple, and assessments of the impact of these three waves of interventions are likewise challenging. As the three waves of feminist and equity-oriented interventions in science education primarily focus on increasing the numbers of girls/women and other under-represented and/or under-achieving groups in science education and science, one option for measuring impact is to measure change by measuring increases student achievement and retention. However, each of the interventions – in different ways – seeks to transform what counts as ‘normal’ within dominant models of science education. Evaluating changes in the values of science education and dominant discourses within the field is more challenging than assessing quantitative changes in student achievement and retention. In part, the difficulty of both creating and measuring this type of change is similar to that described by Jody Roberts (2006) in his study of green chemistry. The goal for green chemists is to change the field of chemistry, so that what is now known as ‘green chemistry’ becomes the norm – what counts as chemical education and practice, in effect. Success, as Roberts points out, means recognition via a growing amount of awareness and adoption followed by a (particular type) of disappearance. In this section, I rely on multiple types of quantitative and qualitative analyses to show how and where (and where not), feminist and equity-oriented science educators have changed science education.

Elementary and Secondary Education

At the macro-level, increases in the number of women and people of color in science education and scientific practice have occurred over the last 30 years. The US gender gap that remains in achievement[8] and participation[9] levels at the elementary and secondary levels of science education[10] pales in comparison to the continuing gaps in achievement along race/ethnicity and class lines. For instance, data from 1999 National Assessment for Educational Progress (NCES, 1999) shows that the gap between the achievement scores of white, Black, and Hispanic students has remained roughly the same from 1977-1999. Data from the 1995, 1999, and 2003 Trends in International Mathematics and Science Study (TIMSS) (International Association for the Evaluation of Educational Achievement, 1995, 1999, 2003) confirms that white students at the 4th and 8th grade levels are scoring up to 122 points higher than their Black or Hispanic peers – whereas the largest point gap on the TIMSS scale by sex is 19 points. In terms of upper-level science courses taken at the secondary level, race/ethnicity is also a factor. For instance, 32.4% of White students and 54% of Asian/Pacific Islander students took physics in 2000. However, only 25.2% of black, non-Hispanic students; 23.2% of Hispanic students; and 17.5% of American Indian/Alaska Native students were enrolled (NCES, 2002). AP/Honors Biology enrolment follows the same pattern: 17.9% white; 25.9% Asian/Pacific Islander; 10.8% Black; 10.8% Hispanic.

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[8] Achievement as measured through comparative data collected by national and international assessments including Trends in International Mathematics and Science Study (TIMSS) (IEA, 1995, 1999, 2003); the Program for International Student Assessment (PISA) (OECD, 2000, 2003); and the National Assessment of Educational Progress (NAEP) (NCES, 1999).

[9] Participation as measured through comparative data on course enrolment collected by analyses such as the High School Transcript Studies conducted by the National Center for Education Statistics (2000, 2004) and the demographic profile of AP exam-takers.

[10] For instance, computer science participation, as measured by the percentage of high school students taking the AP exams, is one area where the gender gap has not narrowed. In 2001, for instance, "approximately 800 girls and 6500 boys took the computer science AB exam" (Clewell & Campbell, 2002).

Parsing achievement scores by class reveals that levels of science achievement remain strongly linked to economic positioning. For instance, 2003 TIMSS data shows that the average science scale scores for US fourth-graders in schools where fewer than 10% of the students are eligible for free or reduced-price lunches was 99 points higher than the average scores for schools where 75% of more of the students are eligible. At the eighth grade level, the average score gap grew to 110 points in 2003. The impact of class position and race/ethnicity intersect in the United States due to the over-representation of people of color in poverty, the increased likelihood that a person of color will be a (potential) first-generation college student, and the tremendous inequities in public school funding between high-income and low-income areas. The situation is further complicated by the high turn-over rate and low levels of qualifications held by teachers working in low-income areas. A similar combination of areas of strength and weakness can be found within higher education and the STEM workforce.

Higher Education and the STEM Workforce

Within higher education and the STEM workforce, there has also been a significant increase in the number of women and other underrepresented groups in science education and scientific practice over the last 30 years. The percentage of women as degree recipients at all levels of postsecondary education, both in science and engineering and other fields, has increased (**Figure 1**: Committee on Women in Science and Engineering, 2001), as has the minority share of science and engineering at the undergraduate (NSF, 2004). At the graduate level, minority graduate student enrollment in STEM fields has also increased. In 1992, white students constituted 78.9% of the US citizens enrolled in graduate programs in STEM fields. In 2002, this percentage had decreased to 68.8%. During this same time period, Asian/Pacific Islander enrollment increased 2.9% (to 9.6% total in

2002); Black, non-Hispanic enrollment increased 2.5% (to 7.3% total in 2002); Hispanic enrollment increased 2.5% (to 6.3% total in 2002); and American Indian/Alaskan Native enrollment increased 0.2% (to 0.6% total in 2002) (NSF 2002).[11] The Committee on Women in Science and Engineering of the National Research Council describes the shift in the number of women science and engineering PhDs as a change from "scarcity to visibility" (2001). However, participation in science and science education for these groups is still shaped by two different types of segregation: territorial (Rossiter, 1982, 1995) and hierarchical (Rossiter, 1982, 1995) (also referred to as horizontal and vertical segregation).

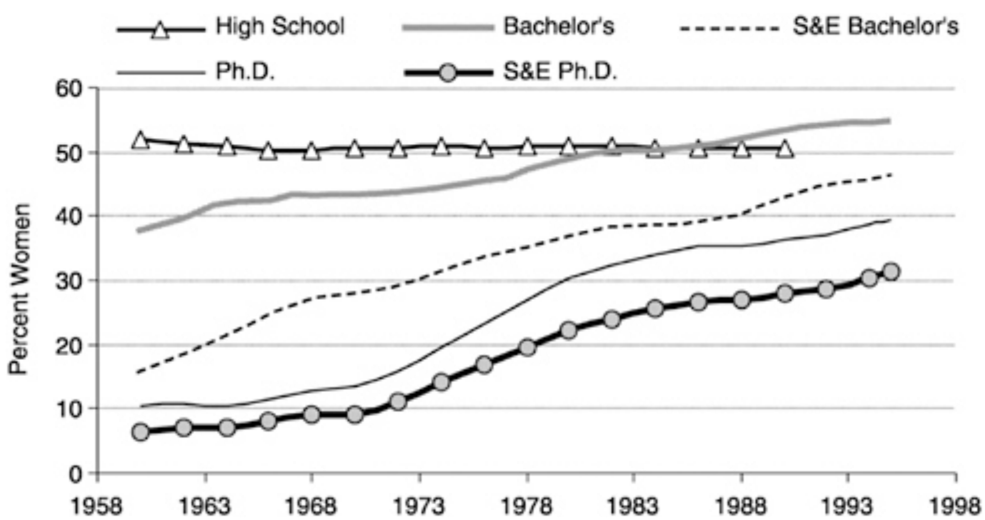

Figure 1: Percent of degree recipients who are women by year. SOURCES: High school data and years before 1966 (Barber 1995); other data (NSF 2000) (Committee on Women in Science and Engineering, 2001, 40).

Territorial segregation refers to the areas in which women and other underrepresented minorities cluster within higher education and the workforce. According to data from the U.S. Bureau of Labor Statistics, women comprised 46.8% of the U.S. workforce in 2003. However, women comprised only 26.1% of the STEM workforce in this year (CPST, 2004). Likewise, the percentage of blacks in the US workforce in 2004 was 10.7%, however they only comprise 4.1% of

[11] The percentages do not add up to 100% due to the NSF category of "Other or unknown."

the STEM workforce. The percentage of Hispanics in the workforce in 2004 was 12.9%, however they comprised only 4.6% of the STEM workforce (CPST, 2005). Within higher education, the number of women who receive doctoral degrees in science and engineering is still significantly lower than the number of men, whereas women now outnumber men in non-science and engineering fields (NSF, 2004). Further, within science and engineering, women are still more likely to receive PhDs in the social sciences rather than the natural sciences (Committee on Women in Science and Engineering, 2001). Within the natural sciences, women are more likely to receive PhDs in the biological sciences than the physical sciences or engineering, as are underrepresented minorities (NSF, 2004). The percentage of women and in the science and engineering workforce (academic and non-academic positions) follows similar patterns (CPST, 2004).

The second ongoing challenge that women and underrepresented minorities continue to face is hierarchical segregation. Hierarchical segregation encompasses what used to be called the "glass ceiling effect," and describes the ways in which the number of women and underrepresented minorities in scientific fields decreases as prestige and salary increase. However, unlike the "glass ceiling," the concept of hierarchical segregation – or, again, what Etzkowitz, et al (2000), refer to as "cumulative disadvantage" – was developed to emphasizes that "difficulties exist at all stages and phases of the scientific career line" (Etzkowitz et al, 2000, p. 15) as women are deflected away from science through a series "critical transitions." As described in a previous section of this chapter, these include the development of gender roles in children, the "weed-out system" facing undergraduate science and engineering majors, a series of critical transitions in the graduate and postgraduate career path such as advisor selection and networking, and scientific organization at the faculty level, including the hiring and tenure process.

According to NSF data (2002) (as analyzed in Clewell & Campbell, 2002), women who earn S&E bachelor's degrees are now more likely to enter graduate school than their male counterparts, but are less likely to expect to earn PhDs (28% compared to 42%). Within the academy, women in science and engineering are less likely to be tenured or tenure-track faculty (with significant variation across disciplines) (CPST, 2005) and full professors and more likely than men to be assistant professors or instructors. Hierarchical segregation also describes the situation for underrepresented minorities in science and engineering university departments. In the "Top 50" science and engineering departments, the chair or department head position is predominantly held by white males – even in disciplines such as sociology where white males make up only 54.9% of the faculty but hold 84% of the chairs (Nelson, 2002).

In the broader STEM workforce, hierarchical segregation is also visible. For instance, within the natural sciences, the percentages of women scientists and women technicians are disproportionate. In 2003, women comprised 34.1% of natural scientists (including faculty) but 47.4% of natural science technicians. This disparity is even more apparent when examining the field of engineering, where in 2003 women comprised 10.8% of engineers (including faculty) but 20.8% of engineering technicians (CPST, 2004). The same pattern is visible within the participation by Blacks and Hispanics in the natural science and engineering workforces (CPST, 2005).[12] Finally, the median annual salary of women is also less than that of men in the same field and at similar positions (NSF, 2004). As well, the median salary of underrepresented minority groups (Blacks, Hispanics, and American Indians/Alaskan Natives) is also less than the median annual salary of whites in natural sciences and engineering (NSF, 2004). Further, analysis conducted by the

[12] However, this pattern does not describe the situation for Asians in the STEM workforce, where Asians are "overrepresented" as natural scientists and engineers (CPST, 2004).

Commission on Professionals in Science and Technology indicates that the salary gap between men and women in certain parts of the STEM workforce may actually be increasing (CPST, 2004).

Changing the Discourse of Science Education

The previous two sections evaluated the efforts of feminist and equity oriented interventions in science education to increase the number of women and other underrepresented groups in science. The data included highlighted continued inequities within science and engineering for women and other under-represented groups. Race and class-based achievement and participation gaps were highlighted in an effort to show the need for feminist and equity-oriented science educators to move beyond gender/sex in their efforts. According to Schiebinger (1999), the NSF had found that in the 1990s, after corrections for age, experience, and education, discrimination remained the only explanation for the poor positions and salaries of women and minorities in the STEM workforce. This pattern appears to be continuing today, and thus the continued attention by feminist and equity-oriented science educators to increasing the participation of women and other under-represented groups is warranted, if equality in these arenas is the primary goal.

Is mainstream science education today in a better position to support these changes? Have the discourses of science education shifted in response to the three waves of feminist and equity-oriented critiques? One notable shift is that most science education researchers now track sex (and sometimes race and class) as a variable in their studies. As well, when distinctions emerge in studies along sex/gender lines, most science education researchers now describe these distinctions as ‘differences’ rather than ‘problems’ for girls, and there is recognition that a one-size-fits-all pedagogy may be an inappropriate suggestion for science educators to follow due to the diversity of students’ backgrounds. However, have interventions in the ‘nature of science’ and ‘science for citizenship’ also had an impact? In this section, I summarize my effort to assess these types of discursive changes in science education research and practice by mapping publication, citation, and co-authorship patterns related to feminist and equity-oriented publications in the *Journal of Research in Science Teaching* (*JRST*) in a 1998 special issue on "Pedagogies and Science education" (see Lehr (2005) for the full analysis, reprinted in **Appendix I**).

This special issue was part of an explicit attempt to transform the *Journal of Research on Science Teaching* from 1994-99 under the editorship of William C. Kyle, Jr., by providing greater access for feminist and equity-oriented science educators to the mainstream science education community. In 1993, Kyle became editor-elect of *JRST* and established four primary goals for his editorship: to a) reduce the publications backlog; b) broaden the nature of discourse within science education; c) enhance *JRST*'s image within the international science education community; and d) develop four theme issues "that would advance the discourse in science education and inspire critical reflection" (Kyle, *et al*, 1999: 516). These theme issues sought to introduce new perspectives and methodologies for research on: "Science Education in Developing Countries"; "Epistemology and Ontology"; "Policy Perspectives"; and "Pedagogies and Science Education" (Kyle, 1994, pp. 321-322).

The 1998 theme issue of "Pedagogies and Science Education" was described at the time as "represent[ing] the movement of marginalized voices into the discourse of the science education research community" (Cavazos et al, 1998, p. 341). It examined "critical, feminist, and poststructural theories and the implications these have in considering the ideal, 'a science education for all children'" (Barton and Osborne, 1998, p. 339). The issue's guest editors – Angela Calabrese Barton and Margery D. Osborne – argues that the theme issue "force[s] us to confront such questions as: 1) How can historically marginalized students become involved in science?; 2) How can we shape practice and curriculum to address the needs of diverse learners?; and 3) How does reshaping practice and curriculum alter our thinking about the discipline of science itself?" (Barton & Osborne, 1998, p. 340). The articles included in this special issue are part of the Third Wave of feminist and equity-oriented interventions in science education, and thus mapping when these articles are cited and by whom can provide a measurement of the integration of the third wave into the mainstream science education community. Focusing on a special issue is also useful, because much feminist and equity-oriented research published in the three gatekeeper journals remains limited to special or theme issues (Baker, 2002).

The forward-looking citation and co-authorship analysis makes two conclusions evident (**see Appendix 1**). The first is that this intervention has created space for research focused on issues of equity and justice and established a growing network of researchers and practitioners devoted to this cause with links inside and outside the science education research community. The second related conclusion is that while a conversation about equity and justice is now occurring within the science education research community between tightly networked individuals, the broader research community (i.e., those persons outside the research network) has not been engaged nor responded to this intervention – whether positively or negatively. (Baker (2002) reaches similar conclusions about the status of feminist and equity-oriented work within science education.) Based on this analysis, was this particular intervention successful? The answer to this question depends on the intended goals. The guest editors sought "to begin what we hope will be an ongoing dialogue about marginalized discourses and pedagogies within the science education community" (Barton and Osborne, 1998, p. 341). In this, they were simultaneously successful and unsuccessful, carving out a space within the science education research community to foster this dialogue, yet failing to engage the majority of the science education researchers in this discussion.

This pattern of segregation within the science education community can also be seen at the annual conferences of the National Association for Research in Science Teaching, in which "Cultural, Social, and Gender Issues" is one strand in which papers are organized. This strand includes a focus on "multicultural and bilingual issues; ethnic issues; gender equity; and issues of diversity related to science teaching and learning." While it is important and valuable that this strand was established in the mid-1990s, it also creates boundaries between scholars and teachers concerned with equity and the 9 other strands (focused on learning; teaching; teacher education; curriculum, evaluation, and assessment; educational technology; history and philosophy of science; informal learning; and college science teaching) in which research continues "as usual."

HAVE FEMINIST AND EQUITY-ORIENTED INTERVENTIONS CHALLENGED THE HEGEMONIC MODEL OF SCIENTIFICALLY LITERATE CITIZENSHIP?

Have feminist and equity-oriented interventions changed science education? Based on the above analyses, the answer is yes – though many ongoing inequities remain to be addressed. By using 'science for all', the 'nature of science', and 'science for citizenship' as entry-points (or boundary objects), feminist and equity-oriented science educators have created a space for themselves to resist from within mainstream science education. This chapter has documented feminist and equity-oriented resistance to provide a more complicated picture of the 'state of affairs' within science education today than that provided in the previous chapter – to show that appearances of hegemony and unity within science education should actually be understood as a situation of 'structured *dis*unity', in which feminist and equity-oriented science educators are strategically located to challenge hegemonic discourses within the field.

However, have the three waves of feminist and equity-oriented interventions challenged the dominant model of scientifically literate citizenship? Challenging the construction of scientifically literate citizenship has not been the primary goal of feminist and equity-oriented interventions, overall. Instead, each of the waves has focused on making science and science education more inclusive to girls and other under-represented and under-achieving groups. However, there are risks in the construction of non-scientist citizenship that each wave poses, whether or not the non-scientist citizen is conceptualized implicitly or explicitly. We must ask ourselves, what relationship between scientific knowledge and the non-scientist does each wave naturalize?

The first wave seeks to make science more inclusive by focusing on removing gender and racial bias from teaching practices, testing, and textbooks. The explicit goal of making science education 'bias-free' is to increase the achievement and participation of girls and other underrepresented groups in science education and science.[13] The non-scientist and non-scientist citizenship are not explicitly addressed. However, the discourse of this feminist and equity-oriented intervention suggests that the only meaning of 'success' is a choice to pursue further STEM education and careers. Thus, students who are targeted by this intervention who choose not to pursue science – (future) non-scientist citizens – are implicitly categorized as examples of 'failure'.[14] How does this position (future) non-scientist citizens to act?

The second wave seeks to make science education more inclusive by expanding what counts as science and scientific knowledge production practices – rather than making science education

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[13] As an aside, within the context of today's War on Terror and multi-national capitalism, is it a feminist and equity-oriented project to rush to produce more STEM professionals? Should we, instead, seek to challenge US nationalism and global hegemony (and capitalism more broadly) by decreasing the actual numbers of scientists and engineers? Should we, instead, work to address the problem of boys' and men's over-participation in the sciences?

[14] Many feminist and equity-oriented science educators see any suggestion that all students are not future scientists (and thus, that we should think about what feminist and equity-oriented science education for future non-scientists would look like) as an oppressive and conservative move. For instance, at the 2006 American Educational Research Association conference, I was yelled at by another audience member when I made this suggestion following a conference presentation that suggested that employing critical pedagogy in science and math education for students who are not in 'college prep' classes is oppressive because it limits their access to traditional disciplinary knowledge (Brantlinger, 2006).

'gender-free' as many in the first wave set as a goal, the second wave provides models of 'gender-inclusive' and 'multicultural-inclusive' curricula. The goal, again, is to increase the achievement and participation of girls and other underrepresented groups in science education and science – thus raising some problem of non-scientists as failures. However, a further risk to the construction of non-scientist citizenship exists in the ways in which the second wave redefines the 'nature of science' to include practices found in the everyday life of girls, people of color, and poor students. By moving these everyday practices into science education, second wave feminist and equity-oriented science educators seek to attach the epistemic value and privilege of Western science to knowledge production systems and ways of being that are not valued within today's society. However, this shift dangerously implies that these experiences do not 'count' unless they can be called 'science' – perpetuating by extension the value-system of Western science. Why do indigenous knowledge systems, for example, need to be called scientific to be valuable? Why do (future) non-scientist citizens needs to be reconceptualized as always already "doing science" in their everyday life?

The third wave continues to direct attention at increasing the numbers and achievement of girls and other under-represented groups in science and science education – however, it is the third wave that explicitly seeks to re-theorize non-scientists as citizens who can use and produce science as a tool for social justice. Thus, the third wave of feminist and equity-oriented interventions explicitly offers an alternative to the dominant model of scientifically literate citizenship. I recognize that the idea that science can be used and produced by non-scientists as a tool for social justice is compelling for many reasons. Within today's society, science is the "language of power," thus the perceived weight of citizens' groups within scientific and technical decision-making processes can be increased if they are able to marshal what policymakers will understand as 'objective', 'value-free' knowledge. However, the relationship between scientific knowledge and non-scientists in the alternative model of citizenship provided by 'science as a tool for social justice' seems to paradoxically reify the dominant model of scientifically literate citizenship, in that "thinking like a scientist" is, again, the way to act.

CONCLUSION

The following chapter explores in more detail the risks of 'science as a tool for social justice' as an alternative model of citizenship. For now, I would like to focus on what the risks I identified above have in common. Each of the three waves of feminist and equity-oriented interventions in science education continues to assume (whether this is the intention or not) that scientific knowledge (however redefined) must be privileged over all other ways of knowing. Why is this so? At the beginning of the chapter, I suggested that the use of boundary objects as a strategy of resistance has limitations. While boundary objects are "both plastic enough to adapt to local needs and constraints of the several parties employing them," they are also "robust enough to maintain a common identity across sites" (Bowker and Star, 1999, p. 297). This robustness imposes certain limitations on what is possible.

Feminist and equity-oriented interventions in science education do complicate our understanding of hegemony by showing how resistance to dominant discourses can occur within a field and that the appearance of unity and consensus within science education should be reread as structured *dis*unity, However, participation within the field (its institutions, practices, and discourses) simultaneously limits the ability of feminist and equity-oriented science educators to challenge the assumption that scientific knowledge should be privileged over other forms of knowledge. This should not necessarily be surprising, as the choice to teach science (rather than history or English, for instance) is predicated on an assumption that there is something about teaching students scientific content that is important – and perhaps more important than other topics. Even if feminist and equity-oriented science educators come to reject this assumption, their ability to challenge the authority of scientific knowledge is constrained by their desire to remain recognized as science educators by gatekeeper organizations such as the *Journal of Research in Science Teaching* and the National Association for Research in Science Teaching – in addition to challenges posed by the very real constraints of day-to-day teaching practices, such as time limitations, imposed curricula and textbook choices; the rise of high-stakes standardized testing; and so forth.

I do see the work of all three waves of feminist and equity-oriented interventions in science education as valuable. Scientific and technical education serves as an entry point both to careers in the STEM workforce and to a greater voice within today's public and private decision-making practices for non-scientists. Thus, I recognize that it makes sense to work to include all women, people of color, and poor students within these arenas of privilege. However, there is a social cost to continuing to privilege scientific knowledge and scientists within our society as the efforts to increase justice and equity are simultaneously participating in a project of silencing non-scientists. There must be simultaneous feminist and equity-oriented work that directly challenges the authority of science to challenge the dominant model of scientifically literate citizenship. Can this challenge occur from within science education? The analysis in this chapter offers evidence to show that feminist and equity-oriented science educators may be unable to meet this challenge, at least by themselves, because of their participation in and constraint by hegemonic discourses and assumptions within the field. As social justice educators outside of science education, our positioning on the margins better situates us to undertake this work.

CHAPTER 4: THE RISKS OF "SCIENCE FOR SOCIAL JUSTICE" AS AN ALTERNATIVE MODEL OF CITIZENSHIP: SCIENTIFIC KNOWLEDGE AND QUEER RIGHTS

INTRODUCTION

Within today's conservative socio-political context, the idea that scientific knowledge can be used as a tool for social justice is compelling due to the link made between science and truth. Thus, employing scientific knowledge as a tool for social justice works to "speak truth to power," establishing credibility for social justice efforts by bypassing the need to establish the authority of certain moral or political claims over others. Instead, these moral or political claims become "objectified" and thus less "objectionable" within public and private spheres. This strategy is not limited to third wave feminist and equity-oriented interventions within science education. Instead, "science as a tool for social justice" is the dominant approach to arguing for civil rights for gay, lesbian, bisexual, transgender, and queer individuals in our country – employed by social justice-oriented educators both inside and outside science education to combat homophobia.[1]

Within an often hostile and increasingly violent environment, the possibility of enrolling one of the most dominant forms of knowledge within our culture – science – to justify demands for equality for GLBTQ (gay, lesbian, bisexual, transgender, and queer) members of our communities and to make space to even talk about GLBTQ discrimination within educational settings is tempting, and at least initially appears to be a "win-win situation." This science-based discourse for

[1] Most, if not all, readers of this dissertation will be familiar with – and perhaps hold – queer or other social justice oriented critiques of genetic explanations of sexual orientation. However, the dominant "liberal" or "politically correct" position in this country remains the idea that sexual orientation is solely the result of genetics. (For instance, this position is articulated as the only non-oppressive way to understand sexual orientation within the 2005 film *The Family Stone*.) Likewise, as will be shown in this chapter, the genetic reductionist approach to sexual orientation remains the dominant approach for challenging homophobia within K-12 education.

equality is grounded, almost solely, on the argument that homosexuality is natural and unchangeable, and should be understood as "just another human variation" much like hair color or height. This use of scientific knowledge works as a strategic way to challenge religious fundamentalism, both within our classrooms and the larger world, and to resist legislative efforts aimed at further criminalizing homosexuality – particularly at a time in which our discourses of 'diversity', 'tolerance', and 'multiculturalism' seem to have failed or been appropriated.

However, certain dangers exist when we employ scientific knowledge to authorize our social justice work, particularly around issues of sexuality. This chapter seeks to push social justice educators to ask ourselves what we risk when we employ the "homosexuality and science" discourse – that is, "science as a tool for social justice" – to challenge the moral condemnation of homosexuality. Estelle Freedman and John D'Emilio (1997) identify three arenas of knowledge in which homosexuality is policed: religion, medicine/science, and the law. Is it most strategic to argue for human rights and equality by using one of these discourses against another, or can we find a way to move beyond these constraints? Does advocating this approach within our classrooms engage the moral condemnation of homosexuality – or move it aside without critique? Finally, when we employ "scientific fundamentalism" to combat "religious fundamentalism," what relationship between scientific knowledge and non-scientist citizenship does "science as a tool for social justice" naturalize for our students?

TEACHING ABOUT HOMOSEXUALITY IN VIRGINIA: A PLACE OF DANGER

As an anti-oppressive educator within a public university in Virginia, I have watched my K-12 and university colleagues, as well as pre-service students, struggle with the question about whether homophobia and anti-gay violence should even be discussed within the public school system because of the conservative and even dangerous environment in which we live. The fear of educators in Virginia – for themselves and their students – is justifiably palpable, as it is across the country. At Virginia Tech, for instance, the Board of Visitors (the university's governing board) rescinded a faculty offer (approved at all previous levels of university governance) made to the lesbian partner of the highly courted new graduate dean – making the homophobic climate of Virginia Tech into a legally questionable policy overnight. The new BOV policy translated unofficially into "no partners hires for unmarried, queer couples" though the publicly declared reasons included vague references to "budget cuts" – even though partner hires for married, heterosexual couples continue. In addition, the BOV also unilaterally removed sexual orientation from the university's equal opportunity/anti-discrimination clause in March 2003. (This decision was reversed in April 2003 after public outcry, but the position of the BOV on sexual orientation – and the Commonwealth Attorney General who had supported this move – is clear.)

At the state level, lawmakers refused to remove the anti-sodomy law from the law books even after a U.S. Supreme Court decision in 2003 found a similar law in Texas unconstitutional. Persons charged with performing lewd acts in public in Virginia face radically different punishments based on the sex of the persons involved. Virginia preemptively banned gay marriage in 1997 and, as Jonathan Rauch (2004) of the Brookings Institution points out, Virginia is "the only state to forbid even private companies, unless self-insured, from extending health insurance benefits to unmarried couples" (Rauch, 2004, np). And in 2004, Virginian lawmakers passed the Marriage Affirmation Act, which states that "A civil union, partnership contract or other arrangement between persons of the same sex purporting to bestow the privileges and obligations of marriage is prohibited" and that any such union, contract or arrangement entered into in any other state, "and any contractual rights thereby," are "void and unenforceable in Virginia" (Rauch, 2004, np). As Rauch continues,

> In the Marriage Affirmation Act, Virginia appears to abridge gay individuals' right to enter into private contracts with each other. On its face, the law could interfere with wills, medical directives, powers of attorney, child custody and property arrangements, even perhaps joint bank accounts. ... It is by entering into contracts that we bind ourselves to each other. Without the right of contract, participation in economic and social life is impossible; thus is that right enshrined in Article I, Section 10 of the Constitution. Slaves could not enter into contracts because they were the property of others rather than themselves; nor could children, who were wards of their parents. To be barred from contract, the founders understood, is to lose ownership of oneself. To abridge the right of contract for same-sex partners, then, is to deny not just gay coupledom, in the law's eyes, but gay personhood. It disenfranchises gay people as individuals. It makes us nonpersons, subcitizens. By stripping us of our bonds to each other, it strips us even of ownership of ourselves (Rauch, 2004, np).

The situation for the GLBTQ communities and their allies in Virginia is dire. In addition to the challenges posed by these laws, Virginia is also home to some of the most public faces of the Religious Right – Pat Robertson and Jerry Falwell.[2]

Within my own classes – including work with pre-service teachers in the Social Foundation of Education, as well as other courses in the fields of Women's Studies, Science and Technology in Society, and History – almost all of my students condemn homosexuality. For many of the students at Virginia Tech, the approach of "hating the sin, loving the sinner" is a 'progressive' stance on gay,

[2] If you will remember, it was Jerry Falwell (on Pat Robertson's *700 Club*) who, a year earlier following the attacks on September 11th 2001, said that: "What we saw on Tuesday, as terrible as it is, could be miniscule if, in fact, God continues to lift the curtain and allow the enemies of America to give us probably what we deserve. … The ACLU has got to take a lot of blame for this. And I know I'll hear from them for this, but throwing God...successfully with the help of the federal court system...throwing God out of the public square, out of the schools, the abortionists have got to bear some burden for this because God will not be mocked and when we destroy 40 million little innocent babies, we make God mad...I really believe that the pagans and the abortionists and the feminists and the gays and the lesbians who are actively trying to make that an alternative lifestyle, the ACLU, People for the American Way, all of them who try to secularize America...I point the thing in their face and say you helped this happen."

lesbian, bisexual, transgender, and queer individuals. Heterosexism and homophobia are accepted as natural parts of the community. For instance, students consistently address me as "Mrs. Lehr," even though, each semester, I consciously introduce myself as "Jane" or "Ms. Lehr." I respond, each time, by asking my students to think about exactly how many assumptions about me are required to decide that I should be called "Mrs. Lehr." Each time, we count as least four significant assumptions: 1) heterosexuality; 2) a willingness to marry; 3) a married state; and 4) the choice to take my husband's name in a professional setting. Every semester, I encourage or require my students to read Kate Evans' (1999) essay entitled, "Are you Married? Examining Heteronormativity in Schools" in which Evans asks:

> How does an assumption of heterosexuality (or other hegemonic structures) play out within a school? And in what ways are heterosexism and homophobia – indeed, "compulsory heterosexuality" (Rich, 1980, p. 637) – inscribed and reinscribed? How might our interactions with others actively "reproduce compulsory heterosexuality and homosexual repression" (Pinar, 1994, p. 194)? And in what ways is compulsory heterosexuality being resisted and reinterpreted in schools? (Evans, 1999, p. 8)

However, my students – some of whom amaze me with their passion and insightfulness in our conversations about race, class, and gender – are consistently unwilling to critically examine their own assumptions regarding sexual orientation. One student in a Gender and Science course in Spring 2004 actually told me that his calling me "Mrs. Lehr" was an attempt to show respect that I shouldn't reject – despite the fact that he rejected my identity by continually calling me "Mrs. Lehr."

Far more painful than being called "Mrs. Lehr," however, are the overt expressions of disgust and hatred that many students are willing to voice both publicly and privately. As an illustration of the challenges facing educators in Virginia, let me revisit the class I taught on October 22, 2002. The class topic for the day in the Social Foundations of Education was heterosexual privilege and homophobia in U.S. educational contexts. In our previous classes that semester, we had focused on the role of class, race, and gender in shaping historical and contemporary educational practices. In each case, we asked: "How do historical and contemporary discourses about difference shape educational institutions and practices in the United States?"

At the beginning of class, we watch selected excerpts from *It's Elementary: Talking About Gay Issues in School* (Chasnoff & Cohen, 1996), a film aimed at K-12 educators that features discussions with students in 1st through 8th grade and their teachers and administrators, as well as some parents – gay and straight. The film argues that talking about "gay issues" in public schools is necessary because of the ways in which even the youngest of students are already dealing with discourses about what it means to be gay – and know (from playground talk, media sources, and perhaps their parents or older siblings) that they need to do everything possible to not be gay, to not be labeled this way. The film connects these emergent homophobic and heterosexist attitudes to anti-gay violence, and thus pushes all educators interested in issues of student safety to take responsibility to prevent anti-gay prejudice at all school ages.

Prior to each meeting of this class, the students were required to complete readings and prepare to discuss questions I provided beforehand. Our discussion questions for the day were:

- How are masculinity and femininity shaped by heterosexuality, heterosexism, and homophobia?
- How have we learned to speak/not speak, teach/not teach about issues of sexuality and heterosexuality, and lesbian and gay culture and families?
- How are students affected by maintaining "silence" about these issues in our classrooms?

However, this is not what we spoke about.

Instead, my students steered – or rather, pushed – the discussion in two overlapping directions: the first, religious; the second, biological. In both cases, the argument enunciated focused on the perceived naturalness of homosexuality – or rather, the unnaturalness of it. My students enrolled scientific facts that are common to condemnations of homosexuality in the United States: for instance, that same sex sexual behavior does not occur in any other animals; that same sex sexual behavior is unhealthy; that same sex sexual behavior is a treatable disease. At the same time, the same students drew upon Biblical and religious sources to identify homosexual behavior as a sin.

As I continued the conversation with my students, I discovered that what they found most "unnatural" is anal intercourse, intercourse that could not be traced to a script of reproduction. I can still picture one student (an ex-Marine) squirming near the front of the classroom, as he tried to enunciate how "disgusting" the thought of two men having sex was to him. In my frustration, after asking a few questions about birth control and heterosexual sex for non-reproductive purposes, I exclaim, "Well, maybe not here at Virginia Tech, but in other places I *know* that even heterosexual couples sometimes have anal intercourse!" (Shock all around – is the shock because of the sexual practice or because I said anal intercourse as part of our discussion?) By the end of the class, the vocal critics of homosexuality do not appear to be moved. They still do not see the place for even a *discussion* of sexual orientation in any class, including this one.[3]

SCIENCE AS A TOOL FOR SOCIAL JUSTICE IN GAY-INCLUSIVE/ ANTI-HOMOPHOBIA CURRICULA

How can this type of virulent homophobia be addressed? How can educators protect themselves at the same time as engaging in the struggle for justice and equality for GLBTQ individuals? Within anti-homophobia and gay-inclusive curricula, three answers exist. First, some educators frame the

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[3] One of the class assignments was to turn in 5 video responses to films we watched as a class. Students were asked to answer the following questions: What are the film's strengths and weaknesses? Why was the film useful or not useful for this class and in conjunction with the day's assigned readings? In what other contexts would the film be appropriate? Would you consider showing this film in your classroom? Why or why not? As I recently reviewed these responses – turned in at the end of the Fall 2002 semester – I found that over half of the students wrote that they do not think that GLBT issues should be discussed in school – whether because these issues were not a part of the required curriculum and/or moral reasons.

discussion of "alternative" sexual orientations in terms of the physical, mental, and emotional right to safety and human dignity of all students, teachers, administrators, and community members. Second, educators engage the religious condemnation of homosexuality by arguing for alternative interpretations of the religious texts commonly used to portray homosexuality as a sin. (In the Bible, these are Leviticus 18:22 and 20:13; Genesis 19:4-11 and Judges 19:22; Romans 1:26-32; I Corinthians 6:9-10 and I Timothy 1:5-10; and the Gospels.) For instance, Universalist minister F. Jay Deacon (2000) rejects what he calls a "literal" and "legalist" understanding of the Bible. Others have pointed out that it doesn't make sense to only apply a "strict" reading of the Bible to passages dealing with homosexuality – in a literal sense, parts of the Bible also sanction slavery, racism, and sexism.

However, by far the most common approach to combating homophobia and heterosexism from what appears to be a safe place is to enroll scientific authority to argue that, in fact, homosexuality is natural – that is, homosexuality is genetic. In fact, when I gave a talk that included a discussion of my experiences trying to disrupt homophobia as a teacher educator in the conservative state of Virginia at the first International Conference on Teacher Education and Social Justice in June 2003, numerous audience members shouted out during my session that homosexuality is *natural, not unnatural*! This science-based discourse for equality is grounded, almost solely, on the argument that homosexuality is natural and unchangeable, and should be understood as "just another human variation" much like hair color or height. The use of "science as a tool for social justice" in this context is understood to make moral or political claims more objective, and thus less "objectionable" within public and private spheres.

As a strategy for gay-inclusive/anti-homophobia curricula, arguing that homosexuality is natural, innate, and unchangeable – and that differences in sexual orientation are akin to differences in eye color and height – can accomplish a number of goals. First, it positions the educator as speaking from a place of objectivity and neutrality. Second, it addresses the question: "Does talking about homosexuality encourage it?" Wiggsy Sivertsen and Terri Thames (1995) write that, "A major objection that lies behind many educators' reluctance to discuss gay and lesbian issues with their students is the belief that young people may be 'recruited' into a lesbian and gay lifestyle. This reluctance rests on the belief that people make a choice to be gay or lesbian and that children are vulnerable to being swayed into being homosexual." More broadly, as Sivertsen and Thames continue:

> Continuing to believe in the idea of "choice" leads to continuing to debate about the issues of free will, sin, and morality with groups which see it as a "choice," and wastes time which could be spent in more productive discussions. Continuing to believe in the idea of "choice" leads to the perpetuation of pain, guilt, and anger that parents of gay and lesbian young people often feel. ... Continuing to believe in the idea of "choice" implies that children or adolescents who are gay or lesbian decide to be "that way, perhaps having heard a presentation about homosexuality or perhaps wanting to "get" their parents somehow (Sivertsen & Thames, 1995, np).

This genetic reductionist approach to sexual orientation is perhaps particularly compelling from the perspective of current and future teachers because it also can be used to protect one's self and colleagues from charges that GLBTQ teachers are compelled to seduce their students by disrupting the link between homosexuality and a deviant 'lifestyle' by positioning homosexuality as natural.

As a strategy, this approach also provides a way to move beyond a discussion of religious beliefs about homosexuality, and sin more broadly, within the classroom and create bridges between those who oppose homosexuality on religious grounds and those who are homosexual. For instance, the free resource book entitled "What We Wish We Had Known: Breaking the Silence, Moving

Toward Understanding – A Resource Guide for Individuals and Families," which was developed by members of the congregation of the Presbyterian church in Mt. Kisco, New York, uses "new scientific information" to initiate dialogue between gay and lesbian individuals and their estranged families. Framing one's anti-homophobic work via genetics also allows educators to address the debate about where students should learn about sexual orientation (home vs. school; parents vs. teachers); and argue against reparative therapy as championed by organizations such as the National Association for Reparative Therapy (NARTH) and the "ex-gay" movement.

Sexual Orientation and Scientific Knowledge in the Non-Science Classroom

Warren Blumenfeld has played a key role in establishing the dominance of the genetic and immutable understanding of sexual orientation within education literature. I have used Blumenfeld's work in my own teacher-educator seminars and he is cited in many of the gay-inclusive/anti-homophobia resources that I have examined. For that reason, I include his definitions of sexual orientation, sexual behavior, and sexual identity in full here. In his essay, "Adolescence, Sexual Orientation & Identity: An Overview," originally written in 1994 for the Gay, Lesbian, and Straight Education Network's educational materials and website, Blumenfeld writes that:

> **Sexual (or Erotic) Orientation**: This is determined by whom we are sexually (or erotically) attracted – our sexual/erotic drives, desires, fantasies. Categories of sexual orientation include homosexuals – gay, lesbian – attracted to some members of the same sex; bisexuals, attracted to some members of both sexes to varying degrees; heterosexuals, attracted to some members of the other sex; and asexuals, attracted to neither sex. ...
> *Sexual orientation is believed to be influenced by a variety of factors including genetics and hormones, as well as unknown environmental factors.* Though the origins of sexual orientation are not completely understood, it is generally believed to be established during early childhood, usually before the age of five.

> **Sexual Behavior**: This is what we do sexually and with whom. *Though the culture has little or no influence over a persons' primary sexual attractions (sexual orientation), our culture can heavily influence peoples' actions and sexual behaviors.* For example, one may have a "homosexual" orientation, but due to overriding condemnations against same-sex sexual expression, may "pass" by having sex only with people of the other sex.
>
> **Sexual Identity**: This is what we call ourselves. Such labels include "lesbian," "gay," "bisexual," "bi," "queer," "questioning," "undecided" or "undetermined," "heterosexual," "straight," "asexual," and others. Sexual identity evolves through a multi-stage developmental process, which varies in intensity and duration depending on the individual.
>
> *Our sexual behavior and how we define ourselves (our identity) is usually a choice. Though some people claim their sexual orientation is also a choice, for the vast majority, this doesn't seem to be the case.* [italics added] (Blumenfeld, 1994, np)

In these definitions, Blumenfeld sets up a sharp distinction between nature and culture. Sexual orientation is natural and unchangeable. Sexual behavior and sexual identity, on the other hand, may shift in response to cultural pressures and personal choices. This distinction allows Blumenfeld to hold simultaneously to a biological explanation for sexual orientation and recognition that people identify as GLBTQ at all stages of life. Thus, persons who "come out" at later stages of their lives are read as culturally oppressed, and now finally able to realize their "biological destiny."

Blumenfeld's typology is visible throughout gay-inclusive/anti-homophobia curricula and projects. For example, an online website called "SEX, ETC.," staffed by sexuality and health experts who "answer [teens'] questions with honest, accurate information" and are "teachers, doctors, and social workers who know a lot about sexuality and health issues" includes this in its Frequently Asked Questions: "I feel I'm homosexual and don't want to be. Can I change my sexual orientation?" The answer is "No." It reads:

> Basically your sexual orientation is something that is a part of you – just like the color of your eyes and the shape of your nose. So, in general, no, you can't change your sexual orientation.
>
> Some conservative and religious groups claim people change their sexual orientation through prayer or therapy. But this just isn't true. People might change their sexual behavior. Maybe they start having sex with a member of a different gender. Or they might stop having sex altogether. But, that doesn't change their inner feelings of who they find attractive.
>
> In other cases, people's understanding of their sexual orientation changes. Our society generally accepts being heterosexual as "normal." That puts a lot of pressure on lesbian, gay and bisexual people to suppress their true feelings and try to fit in. It seems easier, even if it means being someone you're not. A lot of times, though, people realize they can't pretend for their whole life. So, they come out. They haven't "become" lesbian, gay or bisexual. They've just accepted who they are. (SEX, ETC., 2003).

The Gay, Lesbian & Straight Education Network (GLSEN) publication entitled "GLSEN Safe Space: A How-To Guide for Starting an Allies Program" states that "Though the origins of sexuality are not completely understood, it is generally believed to be established before the age of five" (GLSEN, 2003, pp. 29-30). And, Youth Pride, Inc., a non-profit organization in Providence, Rhode Island, serving "youth and young adults affected by issues of sexual orientation" via a drop-in center, support groups, counseling, social activities, and victim assistance advocacy, among other activities, states in its resource guide for school staff, that sexual orientation is "probably one of the many characteristics that people are born with" (Youth Pride, 1997, np).

The Youth Pride resource guide includes an exercise developed by Denise Johnson at Barrington High School that helps students develop an orientation timeline.

ORIENTATION TIMELINE

Concepts:

- orientation is **established** by age 4 or 5
- orientation is **realized** during puberty
- people **self-identify** as lesbian, gay, straight or bisexual at many different ages

This timeline activity is to help students understand concepts of the development of sexual orientation. Student responses should be kept confidential. The purpose of this activity is to think about how and when sexual orientation develops. Sexual orientation is something that is NOT CHOSEN. Homosexuality, however, is often viewed as chosen and something that can be changed. Review the concepts for this activity and explain that lesbian and gay people struggle with "coming out" to friends and family. Cultural and societal factors may cause lesbian and gay people to self-identify at a much older age. This activity encourages discussion about when sexuality is formed. Explain to students that heterosexuality is assumed until expressed otherwise.

- Have students draw a timeline.
- Have them write their **date of birth** at the beginning of the timeline.
- Next, have them write their **present age** at the end of the timeline.
- Have them draw a circle around the age when they think their sexual orientation is **established**.
- Have them draw a star around the age when people have a first crush or first love (attraction).
- Next, have them underline the age when people know or **realize** they are gay, lesbian, straight or bisexual.
- Finally, have students draw a cloud around the age when people tell others about their orientation (self-identify).

Again and again, the main tool in these examples to argue for equal human rights for GLBTQ persons is the idea that sexual orientation is a natural, unchangeable aspect of each individual.

Sexual Orientation and Scientific Knowledge in the Science Classroom

Some gay-inclusive/anti-homophobic curricula and projects provide suggestions for specific subject areas – most commonly, life science or biology classes. In the same way that the use of scientific knowledge "objectifies" arguments for equal rights, the science classroom is seen as a neutral, apolitical, objective site of education. Thus, scientific subject areas are understood as an ideal site to speak "truth to power." For instance, the P.E.R.S.O.N. Project Organizing Handbook (Public Education Regarding Sexual Orientation Nationally) states that, "Regardless of the content of their discipline all science teachers have a contribution to make in anti-homophobia education. Of course teachers of the hard sciences will have less occasion to relate sexuality to their subjects; however they can do some things" (Marshall, Kaplan & Greenman, 1996, np). In biology and life sciences, the P.E.R.S.O.N. Project recommends that:

1. Teachers may present some of the latest research and theory on the biological etiology of homosexuality.
2. Teachers may present examples of same-gender sexual behavior among other species.
3. Teachers may present the scientific facts about Human Immunodeficiency Virus (HIV) and its transmission in the context of explaining how AIDS is not a gay disease.
4. Teachers may explain the biology of hermaphroditism and trans-sexuality, emphasizing the differences between these and the homosexual orientation (Marshall, Kaplan & Greenman, 1996, np).

These recommendations are reiterated within a 2001 article from the journal *American Biology Teacher* entitled "Suicide & Homosexual Teens: What Can Biology Teachers Do to Help?" Authors Mike Smith and Mary Ann Drake write that,

> The first step toward being able to help these students is to understand more about them. One of the most common questions about homosexuality heard today is whether sexual orientation is determined by genetics or by early upbringing and societal influences (nature vs. nurture). For example, male homosexuality is widely believed to be the result of having a "strong" mother and a "weak" father. Recent scientific studies, however, have convincingly demonstrated that homosexual orientation is not caused by adverse conditions in upbringing, such as abnormal parenting, sexual abuse, etc. (Bell, Weinberg & Hammersmith, 1981; Remafadi 1990) (Smith & Drake, 2001, p. 3).

Smith and Drake emphasize that in the U.S. a majority of people "lean toward the 'nurture' rather than the 'nature' explanation for sexual orientation by a 47 to 31% margin (Newport 1998). ... In contrast, fully 75% of the gay respondents in the recent Newsweek poll endorsed the 'nature' position" (Smith & Drake, 2001, p. 3). This poll seems to confirm the assertion that linking homosexuality and scientific knowledge is a safe and effective strategy.

Smith and Drake see three primary ways in which biology teachers can help homosexual teens:

- Start with a Personal Inventory – including "What do you know about recent work in behavioral genetics, about the biology of sexual orientation, about same sex behaviors across species, etc.?"
- Reexamine the Atmosphere in Your Classroom
- Address Sexual Orientation In the Biology Curriculum (Smith & Drake, 2001, pp. 6-7)

They recommend that biology teachers "discuss the current biological understandings of sexual orientation as an example of behavioral genetics." Smith and Drake point out that "most human heredity (including sexual orientation) is not determined by simple Mendelian alleles but is polygenic and multifactorial," however they simultaneously argue that while "science takes no position on whether homosexual behavior is right or wrong ... the scientific evidence about the causes of homosexuality and its occurrence can influence a person's opinion about such non-scientific questions" (Smith & Drake, 2001, p. 7).

Smith and Drake endorse a "biopsychosocial model of sexual orientation determination" in which sexual orientation is "determined by a combination of both genetic and environmental factors (Huwiler & Remafedi, 1998) (2001, p. 4), but they make simultaneous arguments that homosexuals cannot change their sexual orientation (2001, p. 5). They continue:

> ... one of the most common arguments against homosexuality is the mistaken notion that same-sex behavior does not occur among animals, i.e. that homosexuality is

> "unnatural" and therefore unacceptable/immoral. A recent review of published field studies of mammals and birds, however, reveals that same-sex behavior occurs in almost every species studied. In fact, "exclusive homosexuality of various types occurs in more than 60 species of nondomesticated animals and birds, including at least 10 kinds of primates and more than 20 other species of mammals" (including lions, giraffes, gorillas, orangutans, and chimpanzees) (Bagemihl, 1999) (Smith & Drake, 2001, p. 5).

Primarily, Smith and Drake draw upon three studies that support the genetic determination of homosexual orientation, moving from what they see as the weakest to the strongest case. First, Smith and Drake point to Simon LeVay's 1991 "discovery of physical differences in the autopsied brains of homosexual males compared to heterosexual males" while noting that "all of the gay males in this study died of AIDS, which could have caused the dimorphism" (Smith & Drake, 2001, p. 3). Second, the authors cite twin studies by Bailey & Pillard (1991); Eckert et al. (1986); Whitam, Diamond & Martin (1993) that offer the conclusion that there is a "preponderance of identical twins who are both homosexual, compared to [a] lower frequency of concordant fraternal twins which is more similar to siblings," which, for Smith and Drake, "strongly supports the conclusion that homosexuality has a large heritable component" (Smith & Drake, 2001, p. 4).

Finally, Smith and Drake summarize the molecular genetic work of Hamer (Hamer & Copeland, 1994; Hamer et al., 1993), who, in examination of the chromosomes of 40 gay brothers, found that "Among these siblings, a statistically significant number – 33 pairs – had received the same region of their X chromosome (q28) from their mother (only 20 would have been expected by chance)" (Smith & Drake, 2001, p. 6). Based on this report, Smith and Drake write that, "not only had Hamer found evidence supporting the genetic heritability of homosexual orientation among these men, but he had mapped the determining locus (sometimes called the 'gay gene') on the X chromosome, explaining earlier observations that homosexuality tends to occur in an X-linked pattern in some families" (Smith & Drake, 2001, p. 6). While noting that Hamer's work has been criticized for various reasons, Smith and Drake write that, "Regardless of these criticisms, Hamer's work is now widely recognized as supporting the conclusion that, at least in some families, homosexual orientation has a strongly inherited component" (Smith & Drake, 2001, p. 6).

THE RISKS OF A SCIENCE-BASED APPROACH TO GLBTQ RIGHTS

Very understandably, then, many social justice educators draw upon scientific knowledge and its genetic reductionist approach to sexual orientation to address homophobia in our classrooms. This move to enroll scientific knowledge is also found within arguments and practices aimed at the project of queering, which is perhaps different than the types of projects described above. For instance, James Sears, co-editor of the book *Queering Elementary Education: Advancing the Dialogue about Sexualities and Schooling*, writes,

> Although sexual identity is constructed within a cultural context, the predisposition for sexual behavior is biologically based. … The precise biology for the "cause" of homosexuality has not been found …. However, the argument that – absent ironclad evidence – homosexuals choose their "lifestyle" is the "equivalent of saying that since we haven't found the gene that governs left-handedness – and we haven't – then left-handed people choose to be left-handed (or, at a minimum, we can't determine if they do so)" (Burr, 1996, p. 9). Genetic evidence coupled with hormonal research, neurobiological science as well as evidence drawn from anthropology to zoology, overwhelm the etiological debates. Thus the old nature/nurture debate is really two sides of the same coin. Sexual identity is constructed from cultural materials; sexual orientation is conditioned on biological factors. The degree to which this predisposition for (homo)sexual behavior is realized is, in fact, a measure of social coercion and personal resolve. The question,

> thus, for educators who teach queerly is not what causes homosexuality but what factors contribute to the homophobia and heterosexism that make coping with one's sexual orientation so difficult (Sears, 1999, p. 7).

This argument by Sears is strikingly similar to the distinctions made by Warren Blumenfeld (discussed above). Sears writes that, "teaching queerly demands we explore taken-for granted assumptions about diversity, identities, childhood and prejudice" (1999, p. 5). But, for Sears, this critical lens is not turned on scientific knowledge – scientific knowledge remains position as objective and authoritative.

As cultural historian Jennifer Terry (1995, 1999) carefully documents in her work on science, medicine, and homosexuality in modern U.S. society, the historical relationship between those who identify or are identified as homosexuals and scientific knowledge is long and complex. At different points and in different contexts, GLBTQ persons have exhibited both skepticism and faith in scientific and medical knowledge – and they have been both empowered and disempowered, in some cases simultaneously. In the 1960s and 1970s, lesbian and gay rights activists challenged the authority of science to define homosexuality as a disease. Today, for reasons including those discussed above, lesbian and gay rights activists often draw upon a discourse of scientific knowledge to make homosexuality 'natural'.

Many have responded to this strategy by offering critiques of the 'science' of today's 'gay science' and its proponents for being incomplete or lacking objectivity. This critique has emerged across the political spectrum – from the Traditional Values Coalition to Jennifer Terry, a progressive educator and researcher. For example, Terry writes that:

> The argument for homosexual immutability betrays a misreading of the scientific research itself. Nothing in any of these studies can fully support the idea that homosexuality is biologically immutable; each study leaves open the possibility that

> homosexuality is the result of a combination of biological and environmental factors, and several suggest that homosexuality may be tied to a predisposition in temperament that could manifest itself in a number of ways. All agree that biological, social, and psychological factors interact to produce and change the signs of homosexuality. Furthermore, these studies cannot comment effectively on the frequency of homosexuality in the general population (Terry, 1999, p. 394).

However, my primary purpose here is not to raise questions about the validity of these particular research findings. I am more concerned with what it means for GLBTQ activists, educators, and allies to believe a) that this science does, or can, or will provide us with the objective truth about sexual orientation; and b) that this should serve as the bedrock from which we build our case for equal human rights. Broadly, I want to question whether this strategy is, in fact, a "safe" strategy.

What are the risks of "science as a tool for social justice"? When we ground our arguments for GLBTQ equality in contemporary scientific research supporting the genetic basis of sexuality:

- What models of citizenship and democracy does this biologically-based argument reflect?
- Is there a distinction between the perceived and actual safety of this argument?
- What will happen to our efforts and arguments for equality when scientific explanations shift?
- How does our support for and reliance upon scientific knowledge in this case directly contradict simultaneous social justice work?
- What is lost in this "normalization" of homosexuality?

What Kind of Non-Scientist Citizenship? What Kind of Democracy?

One of the keenest dangers of adopting a science-based approached to GLBTQ rights to combat religious fundamentalism is that we participate in maintaining the "scientific fundamentalism" that currently competes for the domination of our culture. By "scientific fundamentalism," I mean the dominant model of scientifically literate citizenship identified in Chapter 2, in which science is assumed to be "an important force for human improvement, … offering a uniquely privileged view of the everyday world" (Irwin & Wynne, 1996, p. 6). Scientific fundamentalism argues that all personal and public decision-making processes should be guided by scientific knowledge. As Karen Barad writes, this particular type of scientific literacy and non-scientist citizenship has been hailed as:

> the basis for democratic decision-making about public issues; necessary for global economic competitiveness and national security; crucial for the promotion of rational thinking; a condition for cultural literacy; necessary for gainful employment in an increasingly technologized world; the basis for personal decision-making about health related issues; and necessary for the maintenance of the public image of science (Barad, 2000, p. 225).

The dominant model of scientifically literate citizenship found in the US national science education standards aims to train (future) non-scientists to acquiesce to the authority of science and the state by actively demarcating science from non-science, experts from non-experts, and the rational from the irrational so that scientific knowledge is privileged in all personal and public decision-making practices – producing a system of acquiescent democracy that creates boundaries and serves to reproduce divisions between scientists and non-scientists, reducing the role of the non-scientist citizen to one of docile acquiescence to technical experts.

While, in this case, "we" become the "experts," this model offers a particularly constrained understanding of non-scientist citizenship – a model grounded in concepts of "neutral authority" and "value-free knowledge" that seems antithetical to basic tenets of social justice education. This approach limits our ability to use other forms of knowledge and alternative arguments for equality by participating in a discourse that legitimates science as the one true lens for understanding our world.

Scientific Knowledge – Perceived or Actual Safety?

The use of scientific knowledge to justify the right to safe space raises further questions about what counts as safety. Terry cautions that, regardless of scientists' "attempts to control the implications of their research, there is a growing popular trend regarding biological evidence for things like homosexuality as a possible means for targeting 'carriers' and removing them from the gene pool" (1999, p. 396). Biologist and science critic Ruth Hubbard poignantly argues that while,

> Most of us would be horrified if a scientist offered to develop a test to diagnose skin color prenatally so as to enable racially mixed people (which means essentially everyone who is considered black and many of those considered white in the Americas) to have light-skinned children. And if the scientist explained that because it is difficult to grow up in black America, he or she wanted to spare people suffering because of the color of their skin, we would counter that it is irresponsible to use scientific means to reinforce racial prejudices. Yet we see nothing wrong, and indeed hail as progress, tests that enable us to try to avoid having children who have disabilities or are said to have a tendency to acquire a specific disease or disability later in life (Hubbard, 1997, p. 187).

By participating in and, in fact, emphasizing a discourse of genetic difference, GLBTQ activists and allies may be strengthening public opinions that condemn homosexuality and the wish to root out the 'disease' from our population – pathologizing or "abnormalizing" rather than "normalizing" sexual orientation variation through our reliance on scientific knowledge. What guarantees exist that Hamer's work on the "gay gene" will not be used within the context of fetal testing? What guarantees exist that will keep insurance companies from refusing to provide coverage for individuals with this "gay gene" because it is perceived that they have a greater risk of becoming HIV-positive or contracting other sexually-related diseases? In a state like Virginia – a state that has outlawed contracts between persons of the same sex – what guarantees exist that hate and fear and genetic truths will not combine to create an opportunity to institutionalize even more oppressive regulations?

What will happen when scientific explanations shift?

Cultural historians of sexuality and sexed and gendered bodies provide ample evidence that medical and scientific explanations shift. More importantly, these histories trouble a narrative of linear scientific progress. That is, the dominant framings and findings of research on sexuality often contradict – rather than build off of – the dominant framings and findings of the previous research paradigm and those of the dominant paradigm that followed. Terry's work, for instance, maps a series of shifts between 1869 and 1948 (the publication date of Alfred Kinsey's *Sexual Behavior in the Human Male*), homosexuality "moved from being understood in terms of an innate biological condition afflicting certain individuals to being considered one of the many possible forms of sexual behavior practiced by all kinds of people" (Terry, 1995, p. 130).

Today, we again live in a period in which biological explanations are dominant. Between 1948 and today, homosexuality was classified as a psychiatric illness by the American Psychiatric Association – beginning in 1952 with the publication of the first edition of the *Diagnostic and Statistics Manual of Mental Health Disorders*. According to the *DSM*, homosexuality was treatable with psycho-pharmaceuticals, lobotomy, psychoanalysis, and aversion therapy (Terry, 1999, p. 368). What does all of this tell us? Standard historical accounts of medicine and science – found today, for instance, in textbooks, popular media, and medical practice – often assume that the knowledge of today is superior to that which existed before. However, the lesson we can learn from these more recent cultural histories is that there is no guarantee that today's explanatory model of choice will continue to be dominant or even play a role in tomorrow's explanations. Thus, we must prepare ourselves for the realistic expectation that the dominant explanations of homosexuality will shift. We must also then prepare ourselves for the effect this shift will have on our ability to argue for equality.

Even today, however, while genetic explanations may be dominant, they are by no means the only framework available. While genetics continues to play a role in these other paradigms, it is at once more complex and less central. For instance, as described by Anne Fausto-Sterling (2000), today's neuroscientists provide examples in which social interactions produce physical changes in the nervous system – pointing to the conclusion that brains and nervous systems are plastic. As Sterling argues, a more "likely" explanation of homosexuality will necessary focus on dynamic interactions between a range of factors including genetics, social experience, cognitive development, and so forth. Notably, these interactions will be ongoing and non-hierarchical. In fact, a more exhaustive review of current research frameworks across disciplines may show that the genetic reductionist approach to homosexuality currently advocated by GLBTQ teachers and activists only exists as dominant in textbooks, the popular media, and other arenas of popular culture.

How does our support for and reliance upon scientific knowledge in this case directly contradict simultaneous social justice work?

The discussion of the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Health Disorders highlights my fourth concern about the use of scientific knowledge as the primary argument for GLBTQ equality. In 1973, the APA removed homosexuality from the second edition of the DSM as a result of the gay and lesbian rights movement's efforts to challenge the pathologization of homosexuality, specifically within psychiatric discourses. This important change in the conceptualization of homosexuality occurred at the same times as second wave feminists argued that, "biology is not destiny, and that male and female roles are learned – indeed that they are male political constructs that ensure power and superior status for men" (Koedt (1973); cited in Terry, 1999, p. 378). Jennifer Terry, as well as other cultural critics, has raised the question about how and why a second shift occurred from this moment in the early 1970s to the early 1990s and today, in which gay journalists like Chandler Burr choose to publish statements such as:

> Homosexuality's invitation to biology has been standing for years. Homosexuals have long maintained that sexual orientation, far from being a personal choice or lifestyle (as it is often called), is something neither chosen nor changeable; heterosexuals who have made their peace with homosexuals have often done so by accepting that premise. The very term 'sexual orientation', which in the 1980s replaced 'sexual preference', asserts the deeply rooted nature of sexual desire and love. It implies biology (1993; cited in Terry, 1999, p. 378).

By returning to the "biology is destiny" argument, GLBTQ rights advocates seem to undercut earlier work in the gay and lesbian rights movement to depathologize homosexuality and troubles efforts to demand equality for individuals who do not identify with one of the binary poles of homosexuality and heterosexuality. Perhaps just as importantly, however, this move undercuts simultaneous social justice work occurring today.

For instance, within an era of increased high stakes testing and a constant discourse of failing schools, failing teachers, and failing students, many of us – as teacher educators – seek to challenge the biologically-deterministic link often made between race and poor test performance. Instead, we point to social rather than biological inequities to provide explanations for this persistent "achievement gap" at the same time that we question what high stakes tests actually can and do measure. While questioning scientific knowledge may not be our primary goal in this project, this challenge is implicit as we move beyond genetics to seek other explanations for differences in performance. At a time in which the draw of genetic explanations continues to increase, however, what happens when we base our arguments for social justice in some instances on scientific knowledge and in others reject the notion that this same type of knowledge has any basis at all?

Finally, our reliance upon genetic explanations of difference intersects with the project of liberal multiculturalism – again undercutting other social justice efforts. Liberal multiculturalism primarily focuses on addressing issues related to social diversity by celebrating differences, for instance, including non-Anglo-American foods, holidays, or cultural traditions within the educational space. However, liberal multiculturalism ignores the social inequalities attached to these cultural differences, marginalizing the difference that matters – who has power and who does not? Instead of paying attention to these social patterns of haves and have-nots, liberal multiculturalism focuses on individuals, taking for granted that "if individuals are taught to give up their individual prejudices and treat everyone the same, we will 'all get along', and any remaining limits to equal opportunity will simply disappear" (Berlak & Moyenda, 2001, p. 94). The genetic science of sexuality also supports an individualist rather than social understanding of difference. By teaching our students that variations in sexual orientation are akin to differences in hair color or height, we teach them to ignore the history of oppression of GLBTQ persons. Further, liberal multiculturalism allows students to "opt out" from challenging homophobia and heterosexism embedded within institutional structures, as long as they are "nice" to their gay friends." In the meritocracy of liberal multiculturalism, the "failure" of any GLBTQ individual is the result of individual choices – not genetics, not sexual orientation, and definitely not any social structures.

What is Lost in the "Normalization" of Homosexuality?

I want to briefly turn to the discussion of the "normalization" of homosexuality, although space does not permit a full exploration. I am aware that many gay and lesbian activists will find my position 'queer' – and indeed, that is intentional. The debate over the genetics of sexuality within the broader GLBTQ and allies' communities highlights a tension between liberal and radical politics –

much as a related debate over gay marriage does. However, even those of us who choose monogamous relationships must ask ourselves: What does it mean to talk about GLBTQ sexuality as "just like" heterosexuality? What do we lose in this process? Again, I turn to Jennifer Terry who asks:

> What would it mean if "homosexuality as we know it today" became reduced in the popular imagination to a strip of DNA, or to a region of the brain, or to a hormonal condition? What would we lose in the defensive move to believe science to be our rational savior and to base our politics in biology? What does science do *for* us? What does it do *to* us? And where can we turn for new questions of the self and new ways of *performing* – as opposed to biologically manifesting – deviance? (Terry, 1999, pp. 396-397).

As we struggle to contain sexuality in the two poles of monogamous heterosexuality and monogamous homosexuality, how many individuals are we silencing in the same way that we have been silenced and made invisible? When we accept monogamous heterosexuality as the model for our relationships – which we seem to do when we rely upon genetic explanations for sexuality – what political stakes are tied to this decision?

CONCLUSION

I was working on revisions to this chapter two days after the 2004 election cycle ended – sitting in the very same Barnes & Noble that I sit now[4] as I revise, yet again, the conclusion to this chapter. On November 2, 2004, the U.S. public re-elected George Bush as president of the United States and 11 states passed ballot initiatives that not only constitutionally outlawed gay marriage, but also, in many cases, made civil unions between same-sex partners illegal. On November 4, 2004, the cover of the *Daily Mirror* (United Kingdom) asked: "How can 59,054,087 people be so DUMB?" Similar

[4] March 13, 2006

questions were being asked within democratic and progressive circles in this country – however, it may be inaccurate to point to ignorance as a determining factor in the election. Instead, it appears as if U.S. voters deliberately chose homophobia (and imperialism). In response to the election results, the mainstream press had provided a narrative about "Moral Moms" and "Values Voters." When did hate become a moral value?

Of the countless press releases and election analyses I received in my in-box in the 48 hours after the election occurred in response to these very visible and deliberate efforts to deny GLBTQ persons equal human rights in this country, one commentary in particular stood out. A medical student named Ian Hoffman (UMDNJ) posted a commentary to the Direct Action Interest Group listserv of the American Medical Students Association entitled, "What happened 11/2/2004?" In this public post, Hoffman asked: "Why did it happen?" and answered: "Our morals are the new battleground of political thought. There is a movement that is officially entrenched in American politics to make morals *the* issue of our times, and it is framing every issue in politics, from foreign to domestic." Instead of acquiescing to the moral framing of homosexuality and gay marriage, however, Hoffman calls on his readers to see that "Same-sex marriage is not an attack on family, not a denigration of the moral fiber of America, it is an issue of all people being equal, regardless of their *biology*, *biology such as the color of their skin, their ethnic origins, their abilities, and especially now, the biological programming of their brain in terms of their sexual preference*" (italics added).

In the next section of his essay, Hoffman asked: "How did it happen?" Here, speaking to the mostly medical student members of this listserv, Hoffman wrote: "We failed. Simple. The medical community who understands the issue of the *biological basis for sexual preference*, failed in its ability to even attempt to address this issue in a wide-spread way. … I have to say that we, as the medical community, are complicit in allowing this to happen. ... we failed to recognize that we had ballot measures that attacked entire segments of our population based on their *biologically-based sexual preference* ... As physicians, future physicians, and health-care providers who care about how policy effects our patients, we had a duty to let the American public know about the *biological issues at hand*. Yet not once in the last 6 months leading up the election did I hear us talking about this issue in any capacity that would make a difference. It was allowed to slip under the radar of us all, and now we are waking up to a world that we can hardly believe" (italics added).

Finally, in a section entitled "What can we do about it?" Hoffman wrote: "This is where the pep-rally speech comes in. It is hard to muster the strength right now, but let's see what happens. Start by asking yourself a question: *'Do you feel that sexual preference is governed by biological factors such as the hardwiring of the brain?'* Keep on moving down a line of thought: 'Do you feel that two adults who have a loving, committed, beautiful relationship, should be sanctioned by the state?' Okay, keep going: 'Do you think that laws that prevent the state from sanctioning certain adult members in loving relationships should be allowed?' Finally, ask yourself the most important question of all: 'If you would have been capable of taking part in the civil rights movement of the 1950's and 1960's, would you have gotten on the buses to go to Alabama, Georgia, Louisiana, knowing what you know today about civil rights?' ... So ask yourself the famous question, 'are you on the bus?' And more importantly, are you willing to get on that bus, and put your fight for rights above all else, at the cost of putting all else aside, all the other issues we hold dear. Today is not a day of mourning. It is the birth of a new civil rights era. November 3, 2004 is a call to action. Let's get ready to get on the bus" (italics added).

Since November 2004, attacks against the rights of gay, lesbian, bisexual, transgender, and queer individuals have continued in this country. In this increasingly dangerous climate, it may seem as if "science as a tool for social justice" – that is, the genetic reductionist approach to GLBTQ rights – is our only option to fight religious fundamentalism, bigotry, and intolerance. However, reproducing the dominant model of scientifically literate citizenship also has real risks with real world consequences, creating a situation in which the authority of science and the state go unchallenged. Is this a risk we can live with? Or do we need to find other options?

CHAPTER 5: CRITICALLY ENGAGING SCIENCE IN THE NON-SCIENCE CLASSROOM TO TEACH FOR SOCIAL JUSTICE

INTRODUCTION

In the introduction to this dissertation, I identified three questions that emerged from my analysis of university and student discourses in response to an on-campus sexual assault as part of an action research approach to improving my teaching practices: Why is it *natural* to draw on scientific knowledge to create and maintain situations of blatant injustice? Where do we learn to interact with scientific knowledge in this way? And what tools are available to disrupt this process of *naturalization* of oppression within our schools and our society? This project crystallized for me when my students enrolled scientific knowledge to argue that dominant discourses of masculinity and femininity are *natural*, and thus inescapable.

As a whole, this dissertation is a product of my desire to grapple with these questions. Action research is primarily about self-reflection and analysis of actions and discourses, followed by new actions and attempts to produce new discourses. This exploration is at once both private and public, in that I chose to explore these questions in such detail to both improve my ability to teach for social justice, and to initiate a broader discussion on the relationships between social justice, scientific knowledge, and non-scientist citizenship. Making this dissertation public is part of my ongoing action research process, and, in a sense, can be viewed as an opportunity for me to take action based on past self-reflection and to invite broader collaboration in both inquiry and changed practice.

The previous chapters have addressed the first two questions posed: Why is it *natural* to draw on scientific knowledge to create and maintain situations of blatant injustice? Where do we learn to interact with scientific knowledge in this way? And what tools are available to disrupt this process of *naturalization* of oppression within our schools and our society? In this chapter, I provide a situated resolution to the third question by exploring how research in the field of Science & Technology Studies can serve as a primary resource in the construction of new models of scientifically literate citizenship. This chapter marks a new stage in my action research process: action based on reflection (to be followed by a new cycle reflection, collaborative inquiry, and action). This discussion is thus, necessarily, a work-in-progress. However, my hope is that these situated answers will serve as 'points of entry' (Smith, 1987) for the broader discussion and reconstructive project on social justice, scientific knowledge, and citizenship that I wish to promote.

In trying to identify the tools that are available to challenge this use of scientific knowledge to create and maintain systems of oppression and marginalization, I came to realize that my action research project must extend beyond the boundaries of my classroom space (where much practitioner research resides). I needed to understand the ways in which my students (and myself), as non-scientists, had been educated (or trained) to interact with scientific knowledge. Further, I needed to understand how this training situated them to act (or not to act) for social justice. That is, I needed to learn more about *where* non-scientists learn to interact with scientific knowledge and *what* relationships between scientific knowledge and non-scientists are naturalized within these contexts. This grounding was required to enable me to articulate an oppositional narrative that seeks to disrupt the use of scientific knowledge to create and maintain systems of oppression and marginalization.

I chose to focus my attention on the theory and practice of formal science education. While non-scientists receive cues as to how to interact with scientific knowledge from multiple authorities and at multiple locations outside of school (including the mass media, interactions with parents and peers, after-school clubs, museums and science centers, nature parks, and so forth), formal K-12 science education is a requirement for all students – and thus all future non-scientists – in the United States. Thus examining the ways in which formal K-12 science education articulates its vision for the science education of future non-scientists became a necessary part of my project.

My analysis of formal science education in the United States showed me that the "problem of scientific knowledge and social justice" that I witnessed in my classroom is directly linked to the dominant model of scientifically literate citizenship in the national science education standards. As discussed in Chapter 2, the current national science education standards and reform documents in the United States (AAAS, 1989, 1993, 1997; NSTA 1992; NRC 1996) identify "science for all" as the primary goal of science education today. The model of non-scientist citizenship located within the concept of "science for all" defines (and limits) appropriate behavior for non-scientist citizens as acquiescing to the authority of science and the state by actively demarcating science from non-science, experts from non-experts, and the rational from the irrational so that scientific knowledge is privileged in all personal and public decision-making practices. In other words, this model is about establishing limits and constraints on possibilities for action by non-scientist citizens – creating an ideal of what I labeled "acquiescent democracy."

This framework for the science education of (future) non-scientists – that is, scientific literacy for a specific type of citizenship – dominates the research and practice of formal science education today. This model of citizenship and of non-scientist interaction with scientific knowledge is why "science for all" must matter to educators committed to social justice. Today, many proponents of this model of scientifically literate citizenship have adopted the language of 'deliberative democracy', 'public engagement with science', and/or 'dialogic teaching' (Alexander, 2004; House of Lords, 2000; US Congress, 2003; see also: Driver, Newton & Osborne, 2000; Millar and Osborne, 1998; Newton, Driver & Osborne, 1999; Osborne, 2002). However, the assumption remains, in this 'deliberative turn', that non-scientists must adopt the processes of scientific thinking to participate appropriately within personal and public decision-making contexts.

Unfortunately, some of these assumptions about the relationship between science and non-scientist citizenship are reproduced in social justice-oriented approaches to education. As discussed in Chapter 3, feminist and equity-oriented interventions in science education have not focused primarily on disrupting the dominant model of scientifically literate citizenship. However, each of the "waves" of intervention has either implicitly or explicitly offered new conceptualizations of the relationship between science and non-scientist citizenship. For instance, the first wave implicitly categorizes students who do not pursue science education as 'failures'. The second wave's move to make scientific knowledge more inclusive by expanding what counts as science and scientific knowledge production practices suggests that experiences do not 'count' unless they can be called 'science' – perpetuating by extension the value-system of Western science. Finally, the third wave's re-theorization of non-scientists as citizens who can use and produce science as a tool for social justice seems to paradoxically reify the dominant model of scientifically literate citizenship, in that "thinking like a scientist" is, again, the way to act.

At the conclusion to Chapter 3, I suggested that feminist and equity-oriented science educators may be unable to meet the challenge to disrupt the dominant model of scientifically literate citizenship, at least by themselves, because of their participation in and constraint by hegemonic discourses and assumptions within the field of science education. Social justice educators who teach in non-science classrooms are not faced by these constraints in regards to teaching scientific content, nor are our pedagogical practices shaped by the same kinds of assumptions about the role of science in our everyday lives. Thus, "teaching from the margins" allows for more room to create oppositional narratives about the relationship between scientific knowledge and non-scientist citizenship. However, this space is not always utilized. The strategy of situating "science as a tool for social justice" is not limited to third wave feminist and equity-oriented interventions within science education. Instead, "science as a tool for social justice" is the dominant approach to arguing for civil rights for gay, lesbian, bisexual, transgender, and queer individuals in our country – employed by social justice-oriented educators both inside and outside science education to combat homophobia.

Chapter 4 explores in more detail the risks in the model of non-scientist citizenship that "science as a tool for social justice" provides. By adopting a science-based approached to GLBTQ rights to combat religious fundamentalism we run the risk of reproducing the "scientific fundamentalism" that currently competes for the domination of our culture. Scientific fundamentalism argues that all personal and public decision-making processes should be guided by scientific knowledge. While, in this case, "we" become the "experts," this model offers a particularly constrained understanding of non-scientist citizenship – a model grounded in concepts of "neutral authority" and "value-free knowledge" that seems antithetical to basic tenets of social justice education. This approach limits our ability to use other forms of knowledge and alternative arguments for equality by participating in a discourse that legitimates science as the one true lens for understanding our world.

At the end of Chapter 4, I asked if the risk of creating a situation in which the authority of science and the state go unchallenged is a risk with which we can live. Or do we need to find other options than reproducing the dominant model of scientifically literate citizenship? My exploration of the broader context of my action research project – that is, my analysis of mainstream and oppositional discourses and practices in formal science education – has only strengthened my initial desire to locate tools to disrupt this process of *naturalization* of oppression within our schools and our society. Now I know that these tools must also provide an oppositional model of scientifically literate citizenship. The two additional insights that emerged from my engagement in action research found in the previous chapters are the following: 1) social justice oriented non-science educators must take responsibility for offering this resistance; 2) the non-science classroom can – and must – serve as a crucial site for this resistance.

Recently, Wolf-Michael Roth and Angela Calabrese Barton (2004) have suggested a new way for formal science education to play a role in this social transformation via the articulation of a new model of scientific literacy: scientific literacy should be understood as an attribute of communities rather than individuals. In this framework, "science is not [understood as] a single normative framework for rationality but merely one of many resources that people can drawn on in everyday collective decision-making processes" (Roth & Barton, 2004, p. 158) as they engage in the struggle to create a more just and equitable world. This shift can be understood as an emergent and possible "fourth wave" of feminist and equity-oriented interventions in science education. To date, however, the published work Roth and Barton use to illustrate this shift does not differ significantly from what Barton (1998) previously identified as the third wave of feminist and equity-oriented interventions, "situated knowing and learning," and thus this new vision of science education may not be able to escape the naturalization of certain dominant assumptions within science education about the relationship between scientific knowledge and citizenship.

However, what happens if Roth and Barton's new conceptualization of scientific literacy is shifted from science classroom to the non-science classroom? What happens if the non-science classroom becomes a site for intervention in the relationship between scientific knowledge and citizenship? How can scientific knowledge become simply a resource in private and public decision-making practices – rather than the only authority? In this chapter, I provide a situated resolution to the problems and risks associated with the dominant model of scientifically literate citizenship by returning to two moments in my teaching practice: the critical incident described in Chapter 1, in which my students enrolled scientific knowledge to argue that rape is natural; and to my discussion of teaching in the midst of virulent homophobia that I provided in Chapter 4. Here, I suggest that research in the field of Science & Technology Studies can serve as a primary resource in the construction of new models of scientifically literate citizenship.

OPPOSITIONAL MODELS OF NON-SCIENTIST CITIZENSHIP: RADICAL AND STRONG DEMOCRACY

This is not the first work to propose the construction of oppositional models of non-scientist citizenship or of democratic participation in scientific and technical decision-making processes. In addition to acquiescent and deliberative democracy, for instance, a third model of democracy – and non-scientist participation in scientific and technical decision-making – exists, in which oppositional citizenship is valued. Mark Elam and Margarita Bertilsson, drawing primarily on the work of Chantal Mouffe (2000), argue for a model of public confrontation with science based on radical democracy. This model emerges in the context of critiques of neutrality, rationality, and the presumed equality of dialogue participants in deliberative democracy. For instance, Elizabeth Ellsworth (1989) challenges the idea that it is possible for actors to be situated equally within a rational public sphere; Jennifer Gore (1990) identifies disempowering effects of empowerment rhetoric; Mimi Ortner (1992) and Kevin Kumashiro (2002) argue against the possibility of a 'unique, fixed, and coherent' self who can participate as a rational actor; and Megan Boler (1999) articulates the need for emotion in dialogue (see also hooks, 1994). Mouffe's work also challenges the goal of consensus, which, as she writes, "is – and always will be – the expression of hegemony and the crystallization of power relations," because the boundary between "what is and what is not legitimate is a political one, and for that reason it should remain contestable" (Mouffe, 2000, p. 49).

Drawing from Mouffe (2000), Elam and Bertilsson argue that, "By connecting scientific citizenship to the alternative model of a radical and pluralist democracy, room is created for legitimate forms of public confrontation with science and technology outside of deliberative contexts and a new vision of the virtuous scientific citizen" (Elam & Bertilsson, 2003, p. 245). This radical and pluralist democracy values passion and dissent, and reshapes what counts as non-scientist citizenship and legitimate action.

> The radical scientific citizen is fully prepared to participate in demonstrations and direct action aiming to secure a currently denied democratic identity in innovation [research and development decision-making]. Street marches, boycotts and sit-ins and other means of publicly confronting those ruling over science and technology are accepted as legitimate practices of democratic criticism. While the scientific citizen as activist may be taking a partisan position in defense of a particular individual or group in society, they are also to be understood as assuming a moral stance in defense of general ethico-political principles (like scientific democracy), which are accepted as existing through many different and conflicting interpretations subjecting them to continuous contestation (Elam & Bertilsson, 2003, p. 245).

In this model of citizenship, the non-scientists' oppositional participation at all levels of scientific and technical decision-making is recognized as legitimate – rather than 'scientifically illiterate'.

Elam and Bertilsson's call for radical scientific citizenship parallels Richard Sclove's argument for strong democracy in technical decision-making. In *Democracy and Technology* (1995), Sclove employs Benjamin Barber's (1984) contrast between strong and thin democracy to call attention to problems in democracy and public participation today. In the thin democracy of today, "substantive political equality" and "citizens' active engagement in political discourse" are neglected because of a

> preoccupation with representative institutions, periodic elections, and competition among conflicting private interests, elites, and power blocs. Within thin democracies power is less evenly distributed; citizens can vote for representatives but ordinarily have little direct influence on important public decisions (Sclove, 1995, p. 25).

Strong democracy, on the other hand, suggests that, "people should be able to influence the basic social circumstances of their lives, implying a society organized along egalitarian and participatory lines" (Sclove, 1995, p. 25).

What Sclove adds to Barber's vision of strong democracy is the reconceptualization of technology as a polypotent social structure that shapes social experience: "To continue to neglect technologies' broad social dimensions virtually guarantees that we will remain ineffectual in addressing our deepest social problems and sources of personal malaise … existing technologies help constitute the present social order and so constrain social transformation. Until technological concerns are fully integrated into programs of social transformation, such programs will be stunted or abortive" (Sclove, 1995, p. 7). For Sclove, "*If citizens ought to be empowered to participate in determining their society's basic structure, and technologies are an important species of social structure, it follows that technological design and practice should be democratized*" (Sclove, 1995, p. 25).

Sclove's "active citizens" all "govern themselves in at least some public matters at least some of the time, not necessarily "in every instance, but frequently enough and in particular when basic policies are being decided and when significant power is being deployed" (Sclove, 1995, pp. 37-38). Those recognized as scientific and technical experts today continue play a role. However, their role "should be decided by means of strong democratic procedure, with due sensitivity to experts' deep and abiding shortcomings on the specific subject of democracy and technology, and in a manner that ensures that, with respect to experts, lay citizens reclaim their rightful political sovereignty, formally and in practice (Sclove, 1995, pp. 50-51). For Sclove, non-scientist citizens are reconceptualized as experts on the "social."

How can the shift to strong democracy and active citizenship occur? According to Sclove, requisite background conditions include:

> (1) some commonality of purpose, attachment, or outlook among citizens (at a minimum, general recognition of a preeminent interest in living in a strong democracy); (2) some general readiness on the part of citizens to accord higher political priority to advancing important common purposes than to narrower personal concerns; and (3) institutions that foster these circumstances (Sclove, 1995, p. 37).

Strong democracy in technical knowledge production and decision-making thus requires the simultaneous transformation of society and citizenship – but how would this actually occur? In *Democracy and Technology*, Sclove suggests that democratic design criteria should be introduced, and provides "a provisional system of design criteria for democratic technologies" (**Figure 1**). As part of his efforts to democratize science and technology, Sclove established the Loka Institute, "a non-profit organization with the explicit aim of influencing science and technology policy in the direction of overall public good using public inputs, with full public engagement, involvement and participation" (Chaterjee, 2005, np). Sclove has also worked to establish a network of science shops – or community based research centers – in the United States. The Community Research Network is a "trans-national network of research and grassroots organizations conducting community-based research for social change. The mission of the CRN is to create a system through which grassroots, worker, and public-interest organizations and local governments can – by establishing the agenda and controlling the results of research – find solutions to social and environmental problems and participate more effectively in public policy" (CRN, 2004, np).

Toward Democratic Community

A. Seek a balance among communitarian/cooperative, individualizes, and transcommunity technologies. Avoid technologies that establish authoritarian social relations

Toward Democratic Work

B. Seek equal and extensive availability of a diverse array of flexibly schedulable, self-actualizing technological practices. Minimize the social need for meaningless, debilitating, or otherwise autonomy-impairing technological practices.

Toward Democratic Politics

C. Avoid technologies that promote ideologically distorted or impoverished beliefs

D. Seek technologies that can enable disadvantaged individuals and groups to participate fully in social, economic, and political life. Avoid technologies that support illegitimately hierarchical power relations between groups, organizations, or polities.

To help secure democratic self-governance:

E. Keep potentially adverse consequences (e.g., environmental or social harms) within the boundaries of local political jurisdictions.

F. Seek relative local economic self-reliance. Avoid technologies that promote dependency and loss of local autonomy.

G. Seek technologies (including an architecture of public space) compatible with globally aware, egalitarian political decentralization and federation.

To help perpetuate democratic social structures:

H. Seek ecological sustainability

I. Seek "local" technological feasibility and "global" technological pluralism.

Figure 2: Design Criteria for Democratic Technologies (SOURCE: Sclove 1995: 98)

However, what Sclove seems to miss in his efforts to reform old institutions and establish new ones is the connection between formal education and citizenship. Elam and Bertilsson likewise do not address formal education as a site of intervention in the construction of non-scientist citizens. But before citizens *are* citizens (whether active or inactive, radical or not radical), they are *future* citizens, or citizens-in-training. As the previous chapters in this dissertation have shown, formal education, and the ways in which these future citizens are trained to act in relation to scientific and technical knowledge in formal education contexts, is an important – but missed – site for intervention and the transformation of society.

CHALLENGING SCIENTIFIC TRUTHS IN MY NON-SCIENCE CLASSROOM

As a graduate student in Science & Technology Studies and simultaneous instructor in courses in Women's Studies, Science and Technology in Society, and the Social Foundations of Education, I entered these classroom spaces with a pre-existing recognition of the politics of science and technology. I had worked to develop a theoretical lens and oppositional practice that troubled notions of naturalness in relation to the *status quo* of power relations. I understood that science plays a unique role in Western culture today. Scientific knowledge, knowledge production practices, authority, and expertise function as ultimate truth in our society – science speaks *for* nature. Scientific knowledge can then be used to achieve closure in public and private debates, in most cases silencing alternative knowledge systems and knowledge producers. As a research program, STS draws into question what counts as natural (Haraway, 1991; Harding, 1993; E. Martin, 1991; Merchant, 1980), challenges the privileged position of scientific knowledge in our society's decision-making processes (Bowker & Star, 1999; Fuller, 2000; Hess, 1997; Irwin & Wynne, 1996; Jasanoff, 1994; B. Martin, 1996; Nelkin, 1992; Porter, 1994; Shiva, 1988), and redefines the notion of scientific progress (Bijker et al, 1989; Callon, 1986; Kuhn, 1996; Latour, 1987; Shapin, 1996; Shapin & Schaffer, 1985). As such, I already believed that STS frameworks and case studies are imbued with liberatory promise, creating a "forum where people who are concerned with the place of science and technology in a democratic society can discuss complicated technical issues" (Hess, 1997, p. 1).

In fact, in my master's thesis, I had analyzed efforts to increase the public understanding of science. Contrary to stated aims of increasing public participation within scientific knowledge production and decision-making processes, I found that public understanding of science projects reproduce divisions between scientists and non-scientists, reducing the role of the non-scientist citizen to one of docile acquiescence to technical experts. Critically, as I argued then, how we are trained to think about science – or not think about science – embodies different understandings of the status of its knowledge, knowledge production practices, authority, and expertise. This education then shapes one's ability (or lack of ability) to challenge the role of science within our world.

However, critical incidents like those described in my dissertation showed me that the authority of science can shape the ways in which we engage the world at all times – even when the "subject" is not science. Caught in the tension between social justice and scientific knowledge in my non-science classrooms, my immediate reaction was to turn to scholarship in STS to place a critique of science within the official curriculum. In this section, I return to my Spring 2003 Social Foundations of Education class to describe in detail the strategy I used to explicitly create an oppositional narrative about science from the first day of class, which prepared me to deal with 'naturalness' of gender discourses later in the semester. Here, I make the social and historical nature of scientific knowledge (specifically, knowledge about reproduction and fertilization) explicit, using the work of STS scholar Emily Martin (1991) to highlight the gendered context in which scientific knowledge is produced. Martin's article may not be accessible to students of all ages, this lesson can be adapted for a variety of age levels across the curriculum.

The Romance of the Egg and the Sperm

On the first day of the Social Foundations of Education in Spring 2003, I structured the course to immediately engage gender and science through an analysis of what Emily Martin refers to as the "romance between the egg and the sperm" (Martin, 1991). Using the blackboard, we mapped the process of fertilization, paying special attention to the activities of the egg and the activities of the sperm. Students told the story of a passive egg and active, autonomous sperm – very similar to what Martin found in her examination of typical descriptions of reproduction in science textbooks:

> The egg is seen as large and passive. It does not *move* or *journey*, but passively "is transported," "is swept," or even "drifts" along the fallopian tube. In utter contrast, sperm are small, "streamlined," and invariably active. They "deliver" their genes to the egg, "activate the developmental program of the egg," and have a "velocity" that is often remarked upon. Their tails are "strong" and efficiently powered. Together with the forces of ejaculation, they can "propel the semen into the deepest recesses of the vagina." For this they need "energy," "fuel," so that with a "whiplash- like motion and strong lurches" they can "burrow through the egg coat," and "penetrate" it (Martin, 1991, p. 489).

Following our mapping of the relationship between the egg and the sperm, the class then watched the opening minutes of *Look Who's Talking* – the 1989 film with John Travolta, Kirstie Alley, and Bruce Willis as the voice of "Mikey." At the beginning of the film, the viewer sees fertilization happen – much in the same way as we and Martin described: the egg floats to the uterus where it rests; the ejaculated sperm are on a mission, in competition with each other to get to the egg first. What I particularly like about this film is that the voice of the sperm (that is Bruce Willis), then becomes the voice of the fertilized egg, and then finally the voice of the child ("Mikey"). The egg's agency – if it ever had any – completely disappears.

After we watched the film, I asked the students if they wanted to add anything to our map of the fertilization process. The answer was "No," they were satisfied – we had a true, biologically-accurate, objective representation. At this point I began to pose some of the questions Martin raises in her STS research on the fertilization process: Primarily, what is the relationship between our knowledge of the egg and the sperm and our cultural understandings of femininity and masculinity?

Why do we know the egg as a "damsel in distress" and the sperm as the "heroic warrior to the rescue"? Is it possible that our dominant discourses of masculinity and femininity have shaped these "facts"? Is it credible to examine this aspect of the reproduction process and tell a different story if we were to look through different cultural lenses, with different discourses in mind?

Martin – pointing to recent research on fertilization – argues that it is possible to understand the interactions between the egg and the sperm differently. For instance, she describes how researchers at Johns Hopkins, while trying to develop a contraceptive that would work topically on sperm, found that "the forward thrust of sperm is extremely weak," contradicting the "assumption that sperm are forceful penetrators."

> Rather than thrusting forward, the sperm's head was now seen to move mostly back and forth. The sideways motion of the sperm's tail makes the head move sideways with a force that is ten times stronger than its forward movement. So even if the overall force of the sperm were strong enough to mechanically break the [egg's] zona, most of its force would be directed sideways rather than forward. In fact, its strongest tendency, by tenfold, is to escape by attempting to pry itself off the egg. Sperm, then, must be exceptionally efficient at *escaping* from any cell surface they contact. And the surface of the egg must be designated to trap the sperm and prevent their escape. Otherwise, few if any sperm would reach the egg (Martin, 1991, pp. 492-493).

Despite research like this pointing to the necessary agency of the egg, Martin then describes how scientists continue to use gender stereotypes (the "aggressive male," the "damsel in distress," and then the introduction of the egg as the "femme fatale") to make sense of new findings – as she says, "these revisionist accounts of egg and sperm cannot seem to escape the hierarchical imagery of older accounts" (Martin, 1991, p. 498). However, waking these "sleeping metaphors in science" (Martin, 1991, p. 501) offers us, as social justice educators, many opportunities to challenge gendered discourses in our classrooms and in our everyday lives.

Martin's work challenges science by drawing our attention to the situatedness of scientific researchers, the way the gendered values embedded in their cultural frame shape the scientific knowledge production processes in their laboratories. In this case, the scientists *produce what counts as natural*, rather than objectively reading the natural world. Notably, what is classified as "natural" mirrors the unequal gender relations of their everyday lives. Even when "scientific progress" is made, as Martin describes in the article, it is limited by the gendered expectations of the researchers: they resist alternative explanations of fertilization.

How did this oppositional narrative about scientific knowledge create an opportunity for the construction of alternative models of scientific literacy and non-scientist citizenship? What happened in my classroom on the day after the sexual assault? How did I respond to my students' support of the naturalness of dominant discourses of masculinity and femininity? As we left it in the introduction, I was in crisis … my pedagogical goals were challenged by scientific truths. Was this challenge successful or had the groundwork done on the first day of class prepared us to critically engage what counts as natural and to act differently in relation to the authority of scientific knowledge in our everyday lives?

My immediate response to my students' assertion that rape is natural was the following: "Well, if it's natural – and thus legitimate – for men to rape and sexually assault women, what is the one solution to ending rape and sexual assault? [Dramatic pause] We have to kill all the men!" While this caused many of my students to laugh, this rather unrealistic solution seemed to push them to reconsider the naturalness of gender discourses, and the question of whether or not we can intervene in its dominant discourses. We could then continue the discussion. One of my students then said, "Wait, this all goes back to the first day of class and the egg and the sperm. Is that intentional?" After I said, "Yes," he continued: "You set the whole class up for this discussion." While I had not, of course, intended for the sexual assault that occurred the previous day, I did very intentionally foreground a challenge to the authority and legitimacy of scientific knowledge within our classroom which then created the space for us to challenge genetic determinism and sociobiology on the day in question. At this point, I encouraged him to tell the rest of the class what he had posted to the discussion board twenty-four hours previously:

> "Gender, however, is how your sex is portrayed socially." I must say I think that is an awesome line that Tiffany brought up. I mean, think about it… on Day 1 of this class what was the topic about? "The Sperm vs. The Egg". I think it is rather interesting to put it all together now, because at first I thought we were just trying to "b.s." the first day of class. We organized our thoughts of men versus women on day one, and it makes more sense now. Lorber on page 204 of RDSJ [Readings for Diversity and Social Justice, one of our texts] writes, "Gender is one of the major ways that human beings organize their lives." Is that not exactly what we did on the first day of class?? Although I feel a part of the first day was a "get-to-know-you" session, I do think we fell into the pattern talked about by Lorber.

My discussion of Martin's article then became the context for our continued discussion about the dominant discourses of masculinity and femininity – a challenge to the legitimacy and authority of science had been made. Science, naturalness, genetic determinism, sociobiology, masculinity, femininity – all were at least now in question. Space was created for us to stop understanding scientific knowledge as the dominant authority in our everyday personal and public decision-making practices.

For the next class (our second day and last day examining gender, gender roles, and sexism in US educational contexts), I assigned two groups of students to research sociobiology. First, what is sociobiology and what does it say about gender? And second, what critiques of sociobiology exist?

After the presentation of this research to the rest of the class, we continued our discussion about the naturalness – or unnaturalness – of the gender discourses with which we are so familiar. Critically, we were able to have this discussion whether or not all of my students were convinced by it – a major contribution to my social justice teaching practices.

I know for certain that not all of the students walked away from this discussion or from my class convinced that a social justice approach to education is the best pedagogical choice or that the objectivity, authority, and legitimacy of science can be challenged or even that we can talk a different way about the interaction between the egg and the sperm. However, I do feel that with this combination – social justice pedagogies and the critical analysis of science – I provided them with access to the right tools to create greater equity and justice in their classrooms, their schools, and their communities if they choose to do so. They could now more effectively challenge sexual assault. They could also have this discussion in their future classrooms. They could choose to behave differently – radically, actively – as citizens.

One of my students even was interviewed later for a critical article on the university's response to the sexual assault – she brought this up on the last day of class, indicating that she would never have critiqued Virginia Tech's sexual assault prevention policy before this class and would never, never have spoken up about it, signed a petition that critiqued it, and then talked to the college newspaper. In her evaluation of herself at the end of class, she wrote: "I learned that one voice CAN make a difference. What a mind-opener!" For me, her change in perspective throughout the course counts very much as a success – and I see the challenge to the legitimacy and authority of scientific knowledge that we undertook in our classroom as a key feature in her transformation to an active or radical citizen with a critically oriented scientific literacy.

Beyond Nature: Critically Engaging Science to Queer Gay-Inclusive Curricula

In Chapter 4, I identified three common approaches to addressing homosexuality in gay-inclusive curricula. Social justice oriented educators in science and non-science classrooms can:

1. engage the religious condemnation of homosexuality by shifting from literal to more interpretative approaches to religious texts;
2. frame gay rights in terms of the "right to personal safety" by documenting the hate crimes committed against individuals believed to be GLBTQ and discuss the suicide rate of 'queer' or 'questioning' students each year; and/or
3. rely upon scientific knowledge to make the case for GLBTQ rights based on a discourse of genetic reductionism, in which sexuality is reduced to genetic explanations.

As I have indicated, the GLBTQ and allies' communities have chosen, in many cases, to focus on the third strategy – particularly within educational contexts. However, as I described in Chapter 4, there are risks to this approach. Namely, are we reproducing the dominant model of scientifically literate citizenship?

Enrolling scientific knowledge as a tool to teach for social justice is powerful in the context of religious fundamentalism and virulent homophobia. However, another way is possible. What if, instead of relying upon scientific knowledge to naturalize homosexuality, we historicize the science of homosexuality to denaturalize all categories of sexual orientation as a strategy for GLBTQ rights? In my analysis of Chapter 4, I drew heavily upon the work of Jennifer Terry and other cultural historians on the history of homosexuality to argue that the scientific knowledge upon which we rely today will shift – and it may shift in ways that harm our ability to use it to make the case for GLBTQ rights. In fact, as I indicated, contemporary or future scientific knowledge may be used for exactly opposite purposes, in which case we will have participated in our own (re)pathologization. An alternative to relying upon scientific knowledge to authorize our arguments for GLBTQ rights involves the introduction of Terry's narrative – or a similar account – of historical change in the science of sexuality into science and non-science classrooms.

Terry's history allows us to ask questions about the very naturalness of categories like homosexuality and heterosexuality – situating us, and our students, to question the naturalness of privileging one category of sexuality (heterosexuality) over all others and participate in the creation of an oppositional model of scientifically literate citizenship. Students may find Terry's work dense or inaccessible. However, it is possible to ask these types of questions in other ways and with other, more accessible texts and activities.

For instance, Alice Dreger's work on hermaphrodites is very accessible and yet nuanced, and forces readers, as she says, "to realize how variable 'normal' sexual traits are … and [to] start to wonder how and why we label some traits and some people male, female, or hermaphrodite. We see that the boundaries are drawn for many reasons; and could be – and have been – drawn in many different ways, and that those boundaries have as many complex affects as they do causes" (Drger, 1998, p. 5). Teachers can use Dreger's work to then make parallels to the history of the classification of sexual orientation – describing how, for instance, the category of homosexuality was "invented" in the 18th and 19th centuries. In the same way, Suzanne Kessler's (1990) work on "intersexuality" shows the arbitrariness of the sexual categories that most of us believe are based in biological fact. If sex as male and female is not natural, how can categories of sexuality be? As a final example, Kate Bornstein's gender workbook (1998) provides a fun way to explore serious and challenging questions about gender and sexual orientation. While many readers may already be familiar with Borntein's gender aptitude test (found in Chapter 1), the rest of the book elaborates upon a nuanced account of the relationships between bodies, genders, and sexual practices with close attention to power and the ways in which we are taught to do gender and sexual identity – and how we can disrupt this training.

What can be gained by denaturalizing rather than naturalizing categories of sexual orientation? In general, logics of classification rely upon (constructed) oppositions between terms or groups in order to assign meanings. Thus, we understand social categories of race – say, white – by paying attention to what it means to be black. While some classifications appear arbitrary, most are embedded within a deep social and political history – as terms like 'normal' and 'abnormal' become attached to distinctions like that between white and black, half of the binary opposition becomes privileged, the other marginalized. As Terry argues, following Foucault, heterosexuality – the normative, privileged practice in our country – can only be understood by what it is not: homosexuality. Reinforcing that distinction via genetic reductionism may, in fact, reify the gap between privileged and marginalized practice. A way into a new type of discussion about homosexuality and heterosexism may be to focus on this project of classification to trouble the meanings of the distinction between homosexuality and heterosexuality. We can thus make the social and historical nature of scientific knowledge explicit – instead of insisting on that very difference by enrolling scientific knowledge as an objective authority. This allows us to argue for GLBTQ equality beyond nature, avoiding the risks I identified in the previous chapter.

MAKING OPPRESSION UNNATURAL: IMPLICATIONS FOR DEMOCRACY AND CITIZENSHIP

Over the past 2 years, I have struggled each time I have been asked the two questions that everyone I know (and many people I have just met) have asked me at least once: "So, what's your dissertation on?" and "When are you going to be done?" I have to admit that I often don't tell the whole truth when I am asked what my dissertation topic is – typically, I just tell people part of what Chapter 2 is about, and then I am out of time and most people are out of interest.[1] At many points in this process, I honestly haven't known the answer to this question. Now, with the full text assembled, I know that a better answer is required. However, I wish to change the question from "What is your dissertation on?" to "What contributions does this dissertation make to rethinking democracy and non-scientist citizenship?"

What contributions does this dissertation make to rethinking democracy and non-scientist citizenship?

1. Science education is a primary site of training for future non-scientist citizens. This field must thus become a site of analysis for educators and theorists who wish to rethink democracy and citizenship today.
2. The dominant model of scientifically literate citizenship within science education seeks to train future non-scientist citizens to acquiesce to the authority of science and the state in all public and private decision-making practices. The goal is to produce an acquiescent democracy, in which non-scientists actively participate in the continual privileging of scientific authority by adopting "scientific habits of mind" and the "scientific worldview."
3. The dominant model of scientifically literate citizenship encourages – whether implicitly or explicitly – non-scientists to enroll scientific authority to naturalize oppression within our schools and society.
4. Feminist and equity-oriented science educators, by themselves, are unable or unwilling to challenge assumptions in the dominant model of scientifically literate citizenship.
5. Social justice-oriented non-science educators must thus take responsibility for articulating oppositional models of non-scientist citizenship and democracy and challenging the naturalized authority of scientific knowledge in all aspects of our lives.
6. Research in the field of Science & Technology Studies can serve as one resource in our efforts to intervene in the dominant model of scientifically literate citizenship and to support a model of democracy that encourages the critical engagement of and opposition to scientific knowledge and the state.

I recognize that there are risks in the approach to rethinking democracy and non-scientist citizenship that I advocate here, as well as numerous unanswered questions. For instance, should non-scientists

[1] Please note that when I have responded to questions about completion dates for this project, each time I answered I at least thought I was telling the truth!

develop an oppositional relationship to all science and technology? How does the oppositional citizen make public and personal decisions about science and technology? Are some scientific practices better than others? And how does the oppositional citizen know? What if enrolling scientific knowledge is the only avenue available to achieve greater justice and equity? Or what if the science is "right"? How do we scale up from classroom-based interventions to changing democracy as we know it today? Finally, what other resources in addition to STS are available?

These questions have achieved new prominence during the George W. Bush presidency. The relationship between science and the state has changed in comparison to the 1980s. In this new context, mainstream discourses in science education – that is, the dominant model of scientifically literate citizenship – have come to be understood by many on the left as oppositional practices.

Today, it is now "radical" to argue that scientific facts be taken seriously in the context of public decision-making processes. The Union of Concerned Scientists, for instance, argues that politics have trumped facts in decisions regarding climate change; coal mining; lead poisoning; emergency contraception; farm wastes; salmon; the Florida panther; and mountain-top removal mining. Bruno Latour (2003) has also argued that critiques of science and objectivity engendered by research in the field of Science & Technology Studies and other critically-oriented humanities and social science research programs may no longer be useful – in Latour's words: research and curricula that teach that "there is no such thing as natural, unmediated, unbiased access to truth, that we are always the prisoner of language, that we always speak from one standpoint, and so on." STS, according to Latour, once sought to "*emancipate* the public from a prematurely naturalized objectified fact" and "an excessive confidence in ideological arguments posturing as matters of fact." However, now that we are in a situation in which the real danger arises from an "*excessive* distrust of good matters of fact disguised as bad ideological biases" and "when this lack of sure ground is taken out from us by the worst possible bed fellows as an argument against things we cherished," the primary project of STS must shift to "reveal the real objective and incontrovertible facts hidden behind the *illusion* of prejudices."

For many, it is in the battle against the encroachment of creation science/intelligent design in secondary biology courses that mainstream science education looks most "progressive" not "oppressive." As more and more of us on the Left side without question on the scientists' team, does this mean that the concerns I have raised about the dominant model of scientifically literate citizenship are mute? Don't we want students to "think like scientists" if the alternative is that they "think like religious zealots"? Will incorporating research and frameworks from Science & Technology Studies into our classrooms lead to relativism rather than resistance?

These questions about the risks of questioning scientific authority are very real, and I take them seriously. However, it is simultaneously necessary to direct our attention to identifying the risks of not critically engaging the authority of science, scientists, and science educators. For instance, in the case of intelligent design, the conceptions of science, scientific processes, and scientific literacy employed to defend evolution reproduce the dominant model of scientifically literate citizenship that I identify in this dissertation. As well, they restrict the introduction of feminist or other critiques of evolutionary science. Is this the side we are on? Or it is necessary to develop a third position – one that rejects scientific fundamentalism at the same time that it rejects religious fundamentalism?

One way forward may be to revisit discussions of "strategic essentialism" or "strategic identity politics." Within feminism, essentialism refers to "the attribution of a fixed essence to women" and "entails the belief that those characteristics defined as women's essence are shared in common by all women at all times. …. Essentialism thus refers to the existence of fixed characteristics, given attributes, and ahistorical functions" (Grosz, 1989, p. 153; see also Fuss, 1989).

Much feminist work has relied (and continues to rely) upon the notion of 'woman' as an essentialist category of being. However, critics of essentialism (including poststructural and postcolonial theorists) have argued that essentialism ignores and/or trivializes differences among women (for instance, by race, ethnicity, class, sexual orientation, age, dis/ability, etc.) and thereby oppresses some women while privileging others (white, middle-class, heterosexual, etc.). Other critics have rejected the notion of identity as fixed, and instead argued that identity is an ongoing, context-dependent process of construction. Both lines of critique suggest that it is impossible to speak for 'all women' – drawing into question the usefulness of or possibilities for a global feminist project.

Is essentialism a necessary aspect of feminism? Both Judith Butler (1990) and Donna Haraway (1989) argue that it is not only possible but necessary to develop a coalition politics and practices of solidarity that are not predicated on unity or essentialism. "The antifoundationalist approach to coalitional politics assumes neither that 'identity' is a premise nor that the shape or meaning of a coalitional assemblage can be known prior to its achievement" (Butler, 1990, p. 15). However, other theorists such Gayatari Spivak (1987, 1990) and later Butler herself (1999) have suggested that "strategic essentialism" or "strategic identity politics" may play a useful role in the construction of these temporary coalitions. That is, the oppressed can strategically choose to act *as if* they occupy a singular uniform identity to achieve immediate political goals – while at the same time recognizing that this essentialism is constructed.

How is revisiting "strategic essentialism" or "strategic identity politics" useful? This discussion shows that it is possible to continue to theorize and to act to transform the world amidst apparent contradiction, tension and ambiguity. The goal is not necessarily to resolve these tensions, but to continually interrogate the gains and losses of adopting specific political positions at specific moments in time. "Strategic essentialism" and "strategic identity politics" return us to the desire to embrace "both/and" rather than "either/or" when thinking about the relationship between scientific knowledge and non-scientist citizenship. That is, while I do recognize that science may play a useful role in personal and public decision-making practices in specific contexts, I also understand my dissertation as an argument for the continual interrogation of scientific authority in these contexts. It is not enough to ask what we gain through science, but we also must ask what we risk and what we lose.

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APPENDIX I: SCIENCE EDUCATION RESEARCH FOR ALL? AN ASSESSMENT OF AN INTERVENTION WITHIN THE SCIENCE EDUCATION RESEARCH COMMUNITY

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INTRODUCTION

This paper offers an assessment of an intervention within the science education research community that sought to transform the *Journal of Research on Science Teaching* (*JRST*) and science education research, policy, and practice more broadly. In 1993, William C. Kyle, Jr., became editor-elect of *JRST* and established four primary goals for his editorship: to a) reduce the publications backlog; b) broaden the nature of discourse within science education; c) enhance *JRST*'s image within the international science education community; and d) develop four theme issues "that would advance the discourse in science education and inspire critical reflection" (Kyle, *et al*, 1999: 516). This paper analyzes the impact of a 1998 theme issue on "Pedagogies and Science Education" as an intervention within the science education research community.

Described as "represent[ing] the movement of marginalized voices into the discourse of the science education research community" (Cavazos, *et al*, 1998: 341), this theme issue examined "critical, feminist, and poststructural theories and the implications these have in considering the ideal, 'a science education for all children'" (Barton and Osborne, 1998: 339). The issue's guest editors – Angela Calabrese Barton and Margery D. Osborne – argue that the theme issue "force[s] us to confront such questions as: 1) How can historically marginalized students become involved in science?; 2) How can we shape practice and curriculum to address the needs of diverse learners?; and

3) How does reshaping practice and curriculum alter our thinking about the discipline of science itself" (1998: 340).

The included authors contribute to our understanding of science education and science education research as situated within a political landscape. As such, science education practice and research can either perpetuate or challenge the political realities in which they are embedded – that is, the social, economic, and political ideologies of the dominant culture (see also: Shymansky & Kyle 1992). Further, identity (of students, teachers, and researchers) is understood as likewise socially and political situated (Barton 1998, 380). For instance, race matters – not because there are particular ways of knowing innate to different racial categories, but because racial difference is attached to differences in power and access and because these racial histories have shaped experiences of learning and knowing. Finally, the contributors understand what counts as scientific knowledge to be, in part, shaped by the social context in which it was created – at the same time that they recognize that the materiality of the world constrains what types of scientific knowledge can be produced if the demands of empirical rigor are to be met.

The integration of oppositional or marginalized discourses of race, class, and gender is not motivated by the desire to promote anti-science sentiment. Rather, the contributors seek to "equip our students with a degree of scientific literacy that will enable them to appreciate both the vast potential as well as the limitations of science [so that] our students can become effective and credible champions of a scientific enterprise committed to serve all humanity" (Norman 1998, 365). Second, the contributors aim to increase participation in science of underrepresented groups by exploring understandings of the "historical basis of [earlier] exclusion" and then showing "that science has indeed made a break from the practices and ideological commitments that made such exclusion possible" (366). Third, the contributors aim to better meet the goal of science for all by situating science in the everyday lives of students.

In this paper, I ask: How did this theme issue and integration of oppositional histories both challenge and change the science education research community, policies, and practice? This assessment of an intervention within the science education research community is important to those concerned with fostering related changes within science education research, policy, and practice. However, this assessment speaks more broadly to questions of institutional change and the possibilities for intervention within an established research community and creates a space for us to ask questions such as: What are the specific goals of our interventions? How do we know when we are successful? What counts as success?

METHODOLOGY

For this analysis, I conducted a forward-looking citation analysis by recording if and when a future scholar formally makes use of an article from the 1998 theme issue. In addition to mapping citations, patterns of co-authorship were also tracked. The primary data source for this project was ISI Social Sciences Citation Index. For each article included in the theme issue, I conducted a cited reference search to generate a file that contained all articles that cited one or more of the theme issue articles. The cited reference search created a file of 84 citations. After removing duplicate citations, the file contained 68 separate articles published in 18 different journals (**Table 4**).

Journal of Research in Science Teaching	30
Science Education	13
Journal of Curriculum Studies	4
Curriculum Inquiry	3
International Journal of Science Education	3
Research in Science Education	2
Review of Educational Research	2

American Biology Teacher	1
American Educational Research Journal	1
Educational Policy	1
Evaluation and Program Planning	1
Perspectives in Education	1
Public Understanding of Science	1
Reading Research and Instruction	1
Science Technology and Human Values	1
Teachers College Record	1
Theory into Practice	1
World Archaeology	1

Table 4: Journals Included in Citation File

Articles that cited papers from the theme issue were published in each year of the sample, 1998-2004 (**Figure 3**):

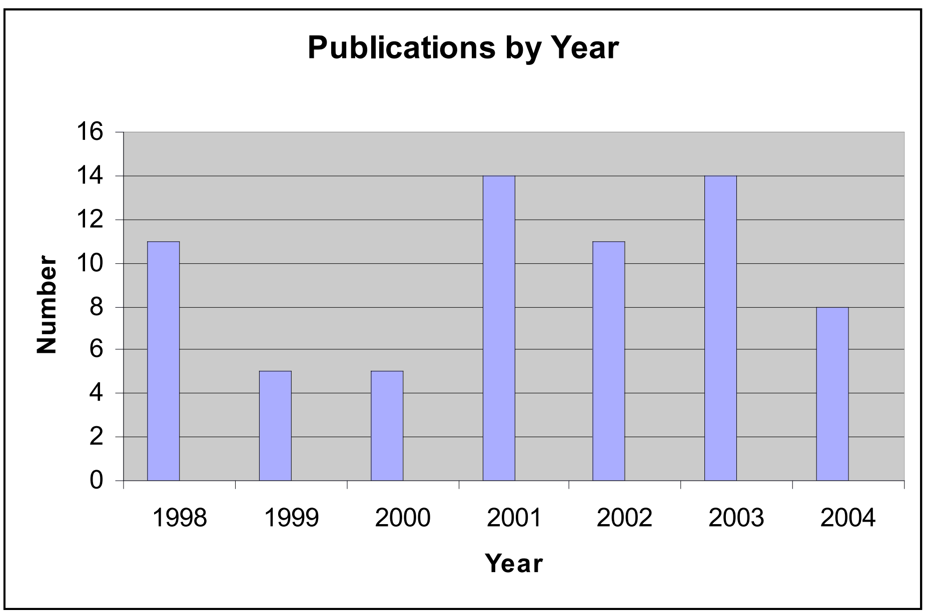

Figure 3: Publications by Year

A social network analysis program (Borgatti, *et al*, 2002) was then employed to analyze the relationships between the theme issue articles and the file of 68 citations. Finally, the data matrix was imported into a program for drawing social networks (Borgatti, 2004) to create s series of images highlighting citation and co-authorship patterns.

As a methodology, bibliometric analysis has both strengths and weaknesses. To fully map the impact of new approaches within particular research communities, one must pay attention to changes in both the social structure and knowledge content of the field. Studying the citation and co-authorship patterns within the field can provide information in both of these arenas. However, MacRoberts & MacRoberts (1988) identify 6 problems in generating the file for analysis: 1) formal influences not cited; 2) biased citing; 3) informal influences not cited 4) self-citing; 5) different types of citations; 6) variations in citation rate related to type of publication, nationality, time period, and size and type of specialty; 7) technical limitations of citation indices and bibliographies, including: a) multiple authorship; b) synonyms; c) homonyms; d) clerical errors; and e) coverage of literature. (For more recent reviews of problems in citation analysis, see Adam 2002; Reedijk 1998.) Despite these important concerns, bibliometric analysis can provide a valuable tool for analysis and is used in this study to offer one mode of assessment of this intervention within the science education community.

In this section, I describe the generated series of images highlighting citation and co-authorship patterns. **Figure 4** is a full citation map. The 15 original articles from the theme issue are represented by black boxes. Articles from the file are represented by red circles. Arrows pointing from a red circle to a black box indicate which of the original article(s) were cited by an article from the file.

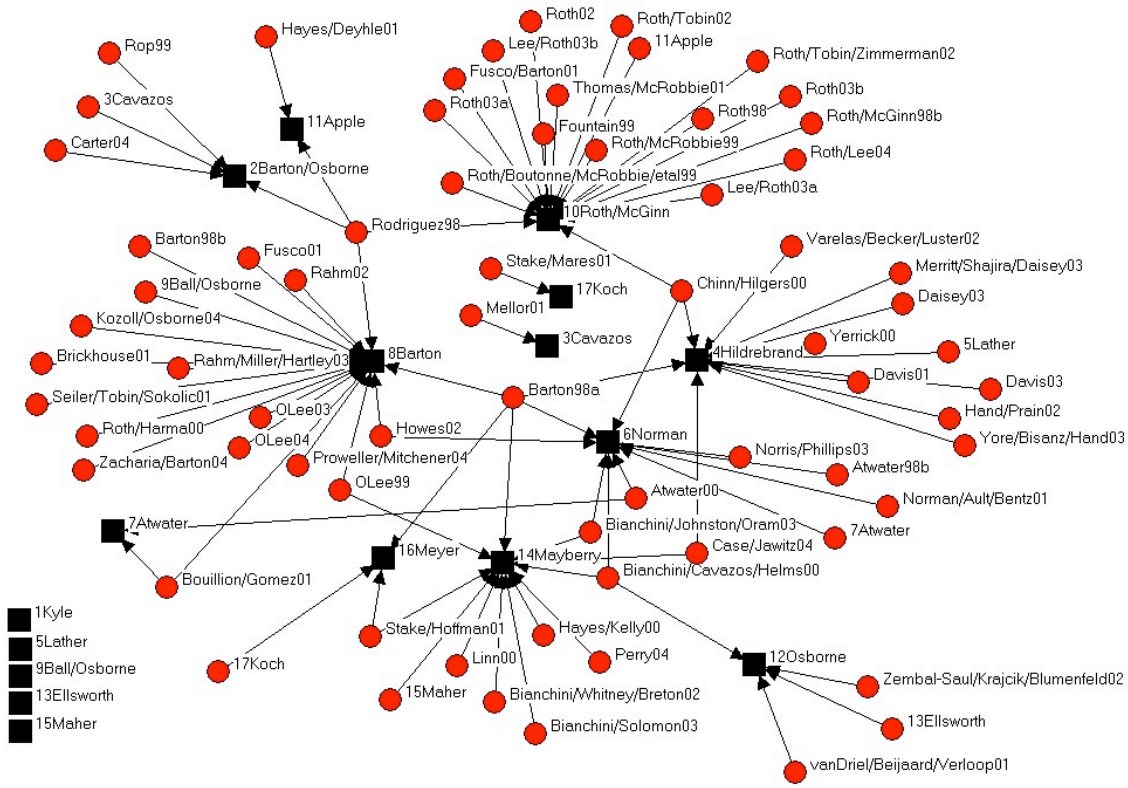

Figure 4: Citation Map 1

This citation map was then recreated in 8 additional iterations by removing citation and co-authorship networks made visible via the network analysis:

1. The February 1998 theme issue includes 6 invited articles that offer "provocative comments" in response to other included articles in order to "draw out the major theoretical points in the articles, to provide further commentary, and to begin what we hope will be an ongoing dialogue about marginalized discourses and pedagogies within the science education community" (Barton and Osborne, 1998: 341). After these responses were removed, 62 articles were left in the file. **(Figure 5)**

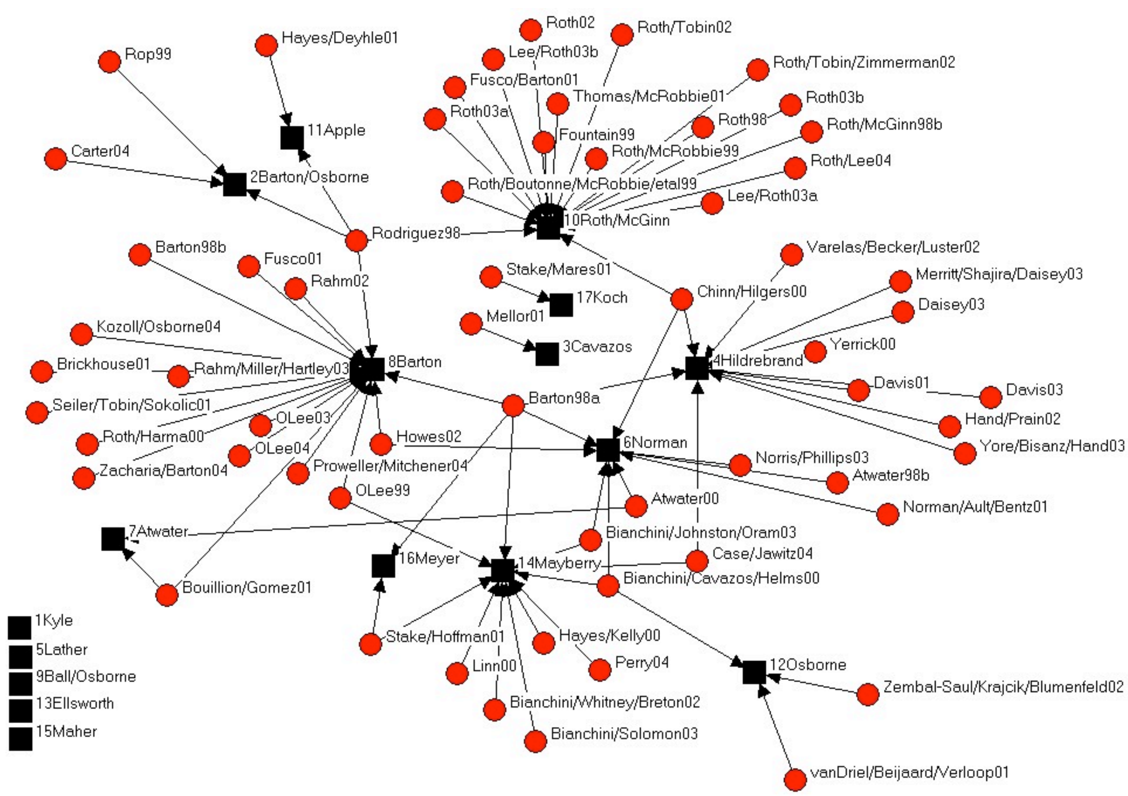

Figure 5: Citation Map 2

2. Self-citations by theme issue authors were removed from the data set, including articles in which theme issue authors collaborated with non-theme issue authors, leaving 46 articles in the file. Self-citations were not removed if the self-citation also cited an additional article from the theme issue. **(Figure 6)**

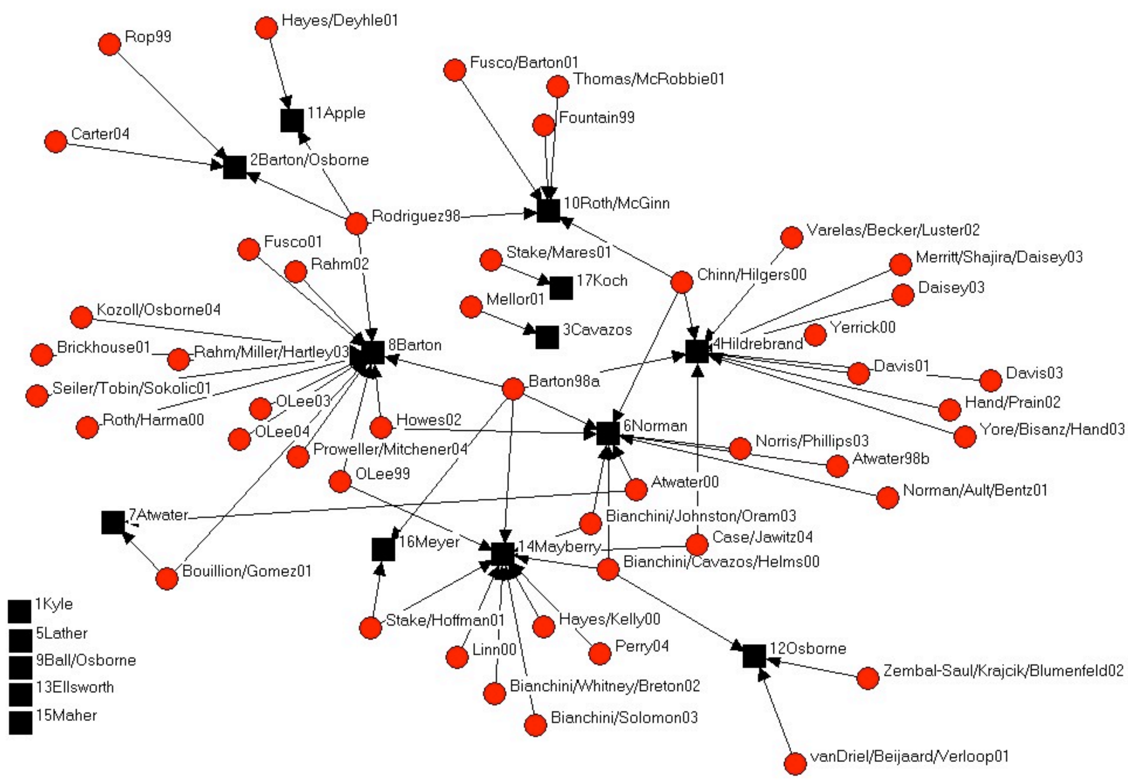

Figure 6: Citation Map 3

3. Any future articles by theme issue authors were removed, including articles in which theme issue authors collaborated with non-theme issue authors, leaving 39 articles in the file. **(Figure 7)**

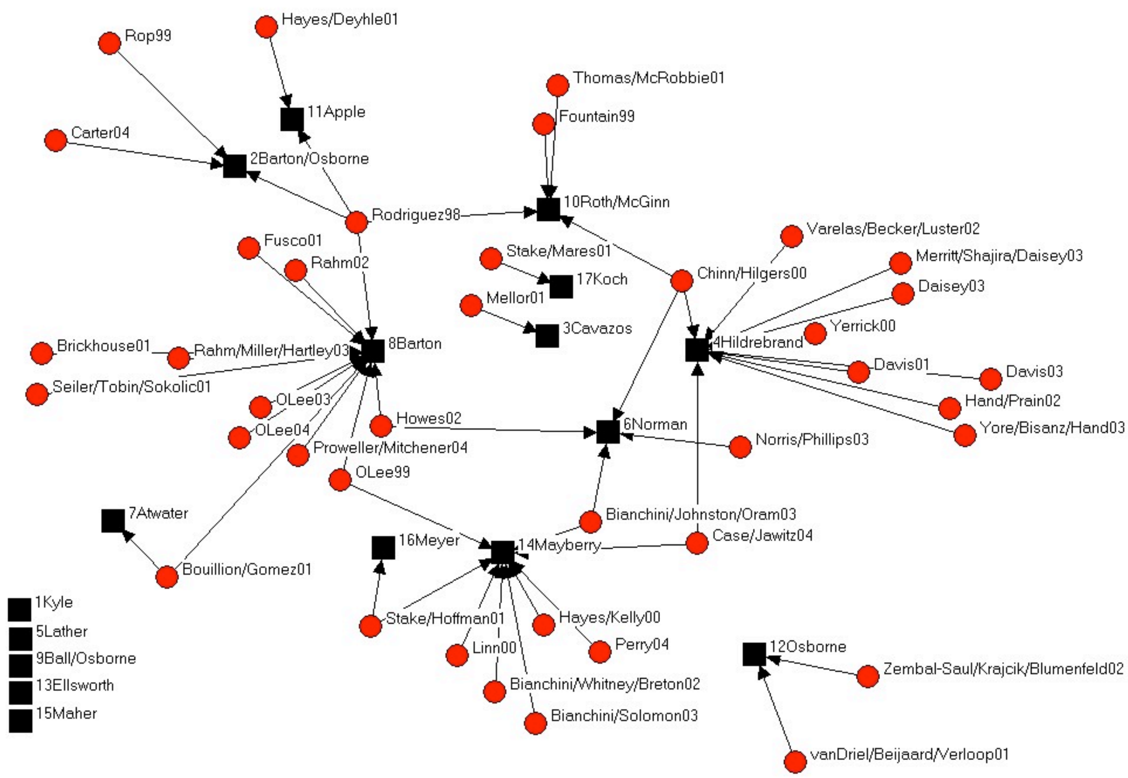

Figure 7: Citation Map 4

4. Publications by persons who have collaborated with theme issue authors in other articles within my sample were removed, leaving 33 articles in the file. **(Figure 8)**

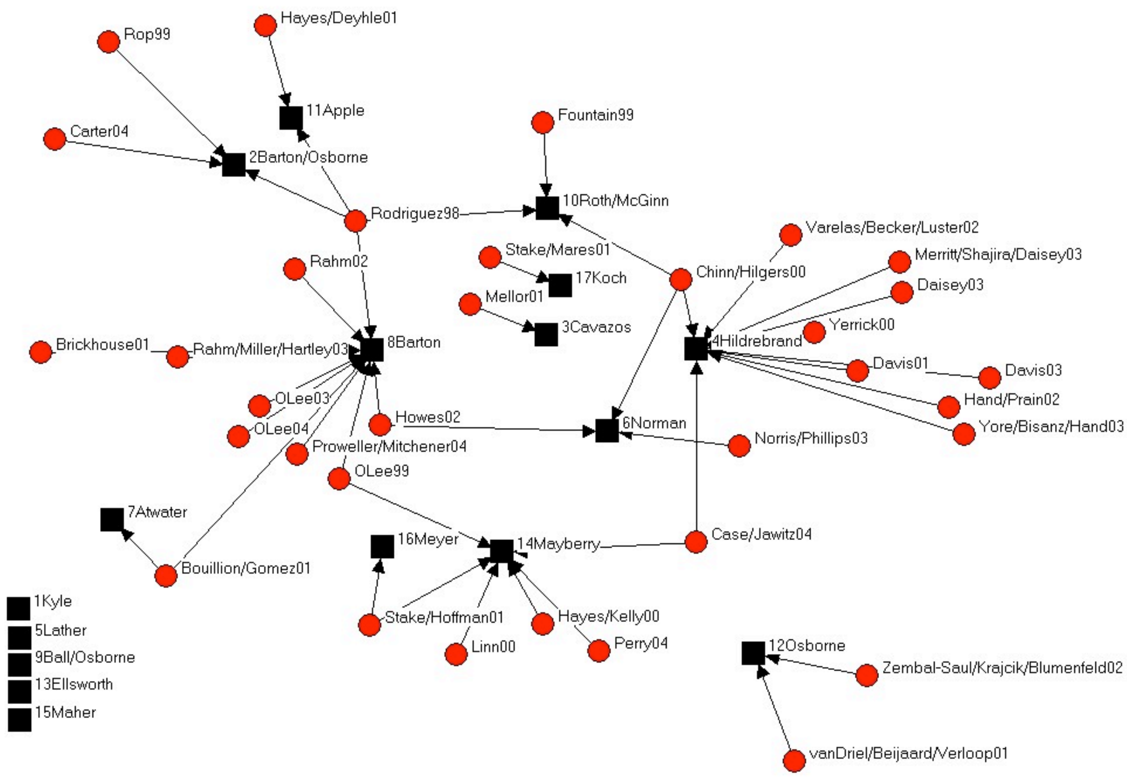

Figure 8: Citation Map 5

5. Articles included in 4 future JRST theme issues co-edited by Angela Calabrese Barton (2001-02) were removed, leaving 28 articles in the file. **(Figure 9)**

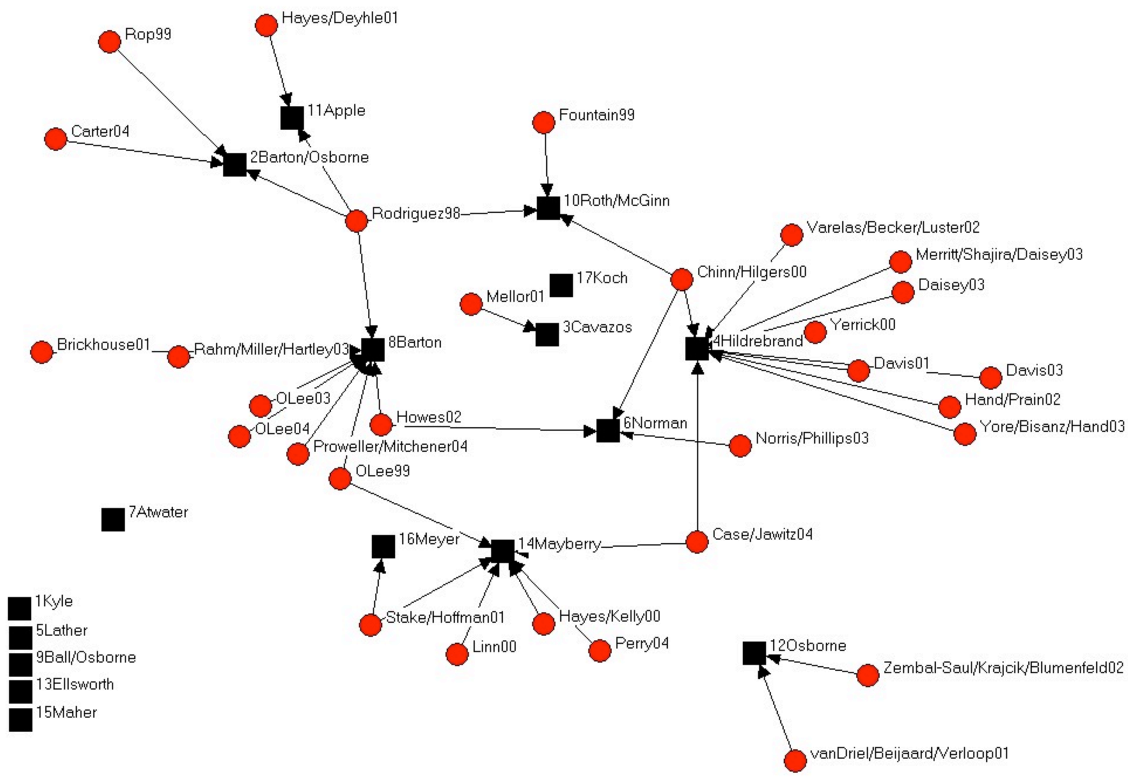

Figure 9: Citation Map 6

6. Any other articles published by authors from the 2001-02 theme issues were removed, leaving 28 articles in the file (**Figure 10**).

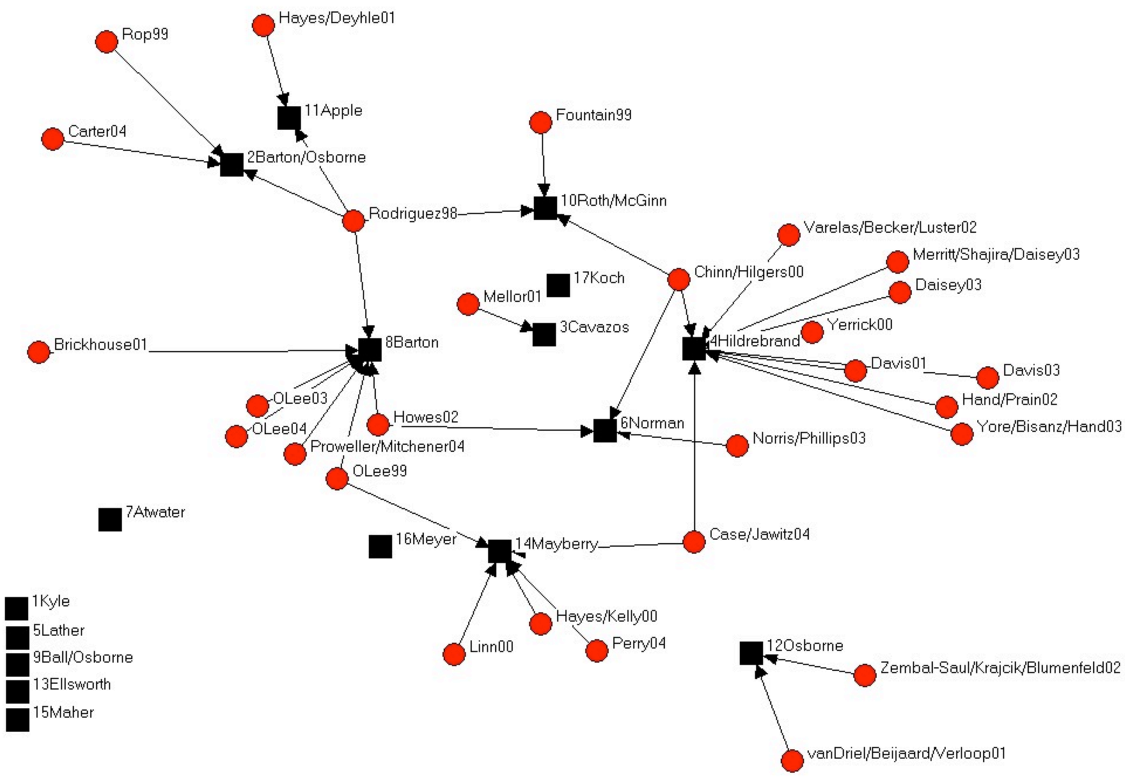

Figure 10: Citation Map 7

7. Remaining articles not published in journals focused on science education were removed, leaving 22 articles in the file. The following journals were included in the science education category: *American Biology Teacher*, *International Journal of Science Education*, *JRST*, *Public Understanding of Science*, *Research in Science Education*, and *Science Education*. **(Figure 11)**

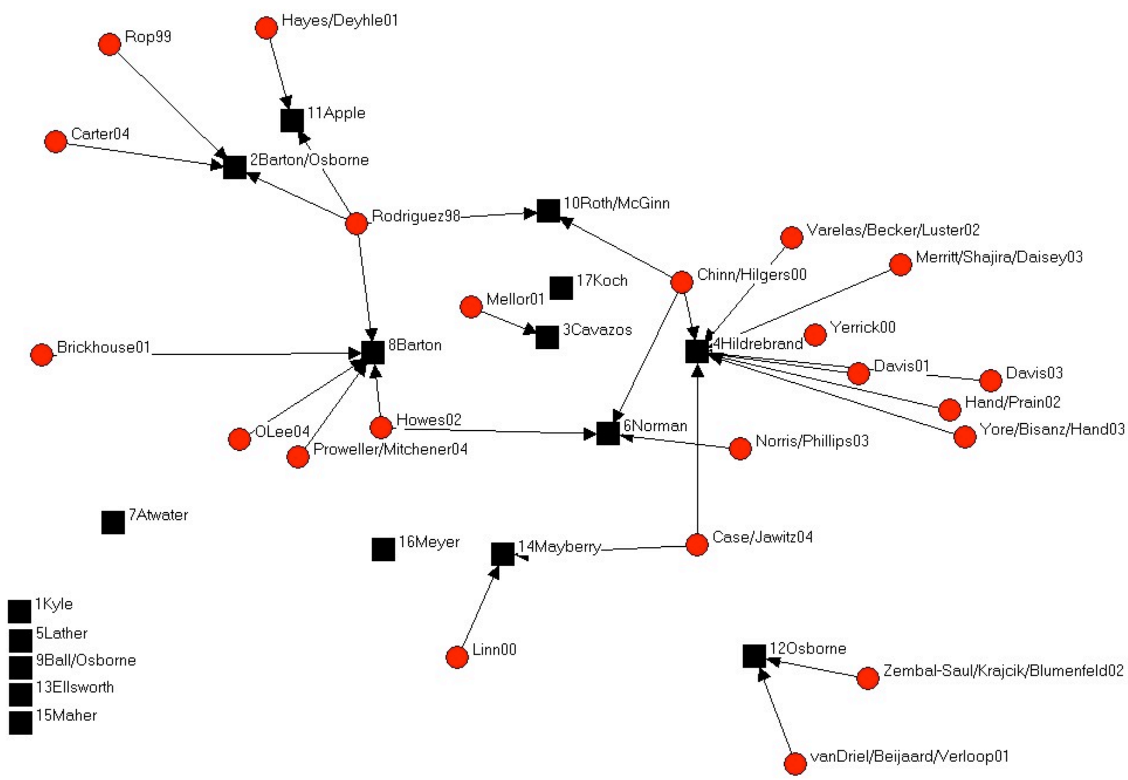

Figure 11: Citation Map 8

8. Finally, any remaining articles not published in *JRST* were removed, leaving 12 articles in the file (**Figure 12**).

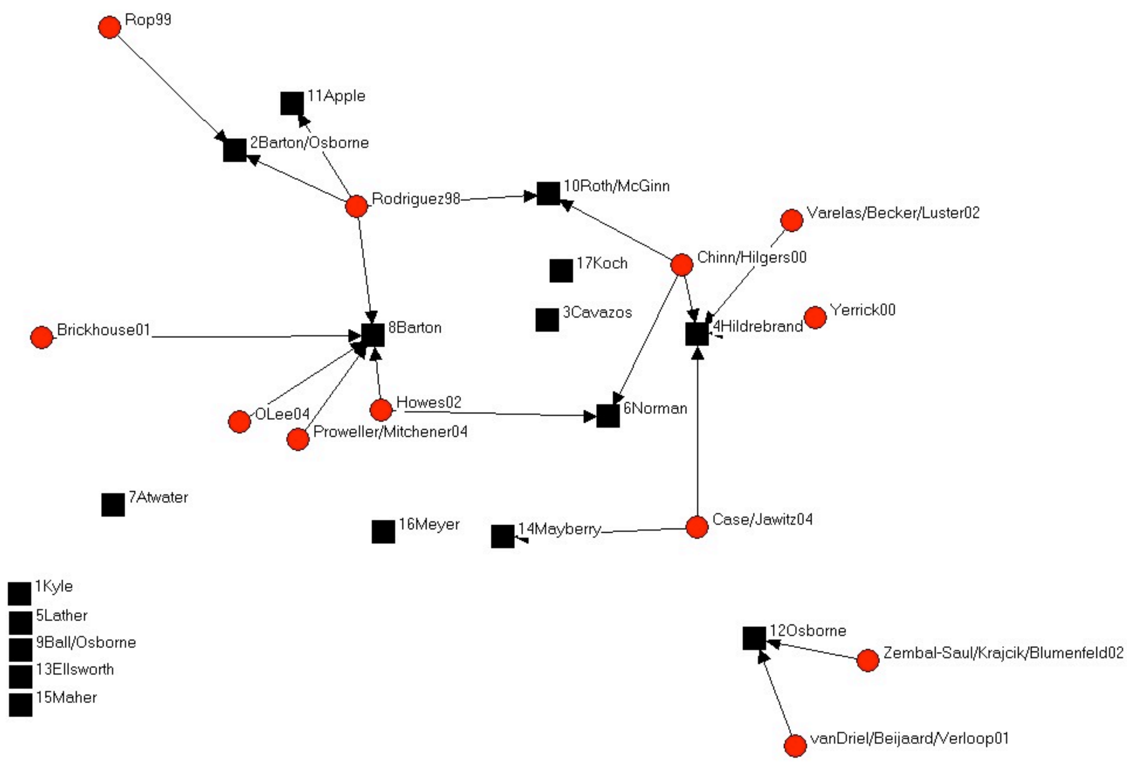

Figure 12: Citation Map 9

CONCLUSIONS AND IMPLICATIONS

This forward-looking citation and co-authorship analysis makes two conclusions evident. The first is that this intervention has created space for research focused on issues of equity and justice and established a growing network of researchers and practitioners devoted to this cause with links inside and outside the science education research community. The second related conclusion is that while a conversation about equity and justice is now occurring within the science education research community between tightly networked individuals, the broader research community (i.e., those persons outside the research network) has not been engaged nor responded to this intervention – whether positively or negatively.

Based on this analysis, was this particular intervention successful? The answer to this question depends on the intended goals. The guest editors sought "to begin what we hope will be an ongoing dialogue about marginalized discourses and pedagogies within the science education community" (Barton and Osborne, 1998: 341). In this, they were simultaneously successful and unsuccessful, carving out a space within the science education research community to foster this dialogue, yet failing to engage the majority of the science education researchers in this discussion. More broadly, this analysis raises questions about the very idea of a "science education research community" – is there one dominant or mainstream community in which we can attempt to intervene or should our goal simply be to establish new research communities that will function alongside those that already exist?

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