The “History and Nature of Science” in the Era of Standards-Based Reform

by

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ABSTRACT

The goal of science education in the United States is promoting scientific literacy for all students. The goal necessitates understanding the nature of science–what science is as a body of knowledge, explanatory tool, and human enterprise. The history of science is one of the most long-standing pedagogical methods of getting at the nature of science. But scientific literacy also encompasses education in scientific inquiry, and in the relationships among science, technology, and society (STS), as well as fact and theory-based subject-matter content. Since the beginning of the standards-based reform movement (circa 1983) many attempts have been made to codify the components of scientific literacy. National level voluntary standards have lead to state standards. Under No Child Left Behind, those state standards have become integral parts of the educational system. Standards are political in nature, yet play the role of intended curriculum. I examine one thread of scientific literacy, the history and nature of science, from its beginnings in science education through the political perturbations of the last thirty years. This examination of "the history and nature of science" through the history of standards-based reform sheds light on our changing conception of scientific literacy.

DEDICATION

This thesis is dedicated to my advisor, mentor, and friend, Jane Maienschein. There are so many things that I could not have done without you.

I also dedicate this thesis to Jessica Ranney, whose presence in my life has resulted in inappropriate amounts of laughter for a workplace environment, not to mention one or two successfully reimbursed travel forms. She has always wanted something dedicated to her; luckily she also deserves it.

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CHAPTER 1

INTRODUCTION

The education of the young is central to the intergenerational stability of a democratic society. The United States education system is therefore one of the flash points of political debate, and so has been in a continuous state of flux known as “reform” for most of the previous century. At various points, the focus of the reform has changed, from course requirements to curriculum to the most recent focus: standards. Standards-based reform efforts are characterized by policies that set forth the knowledge and abilities that students ought to attain by certain points in their education. Documents that enumerate those goals are called standards and curriculum frameworks, or often simply “standards.” The era of standards-based reform began in 1983 with the publication of *A Nation at Risk,* a Department of Education report that called for “higher standards” in education (Tanner and Allen 2002, Taking Science to School 2007, Labov 2006). *A Nation At Risk* was particularly concerned with raising the bar in reading, math, and science.

The goal of standards-based science education is “scientific literacy;” in the US education system, only reading literacy and mathematics facility are higher priorities (Shamos 1996). But while most people feel comfortable agreeing that scientific literacy is an important goal, the concept nevertheless remains ill-defined (DeBoer 1991, 98). The *National Science Education Standards* (1996) gives a definition: “Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity" (22). A review of related literature shows that most definitions of scientific literacy emphasize teaching what science is as a historical and modern process of inquiry, to supplement and give structure to scientific content knowledge (Rutherford and Ahlgren 1989, Hurd, Scientific Literacy: New Minds for a Changing World 1998, Kafai and Gilliland-Swetland 2001). Eugene Chiapetta and others performed a textbook review in 1991 that split scientific literacy into four main "chunks:"

1) content knowledge (facts, theories, laws)

2) investigation (inquiry, experimentation, observation)

3) science as a way of thinking (scientific method, history of ideas, nature of science)

4) interaction of science, technology and society (716-17).

The chief sentiment seems to be that students need something in addition to scientific facts; they need something more that gives those facts structure and applicability. So a key part of scientific literacy is being able to understand the essential qualities of scientific knowledge and how that knowledge has developed over time (Taking Science to School 2007, McComas, Clough and Almazroa 1998). These two concepts are referred to as *history of science* and *nature of science*. They are often referred to as a unit, i.e., *the history and nature of science*. The unification of these ideas indicates their close conceptual ties; the history of science illuminates the nature of science (Rutherford and Ahlgren 1989, Kafai and Gilliland-Swetland 2001).

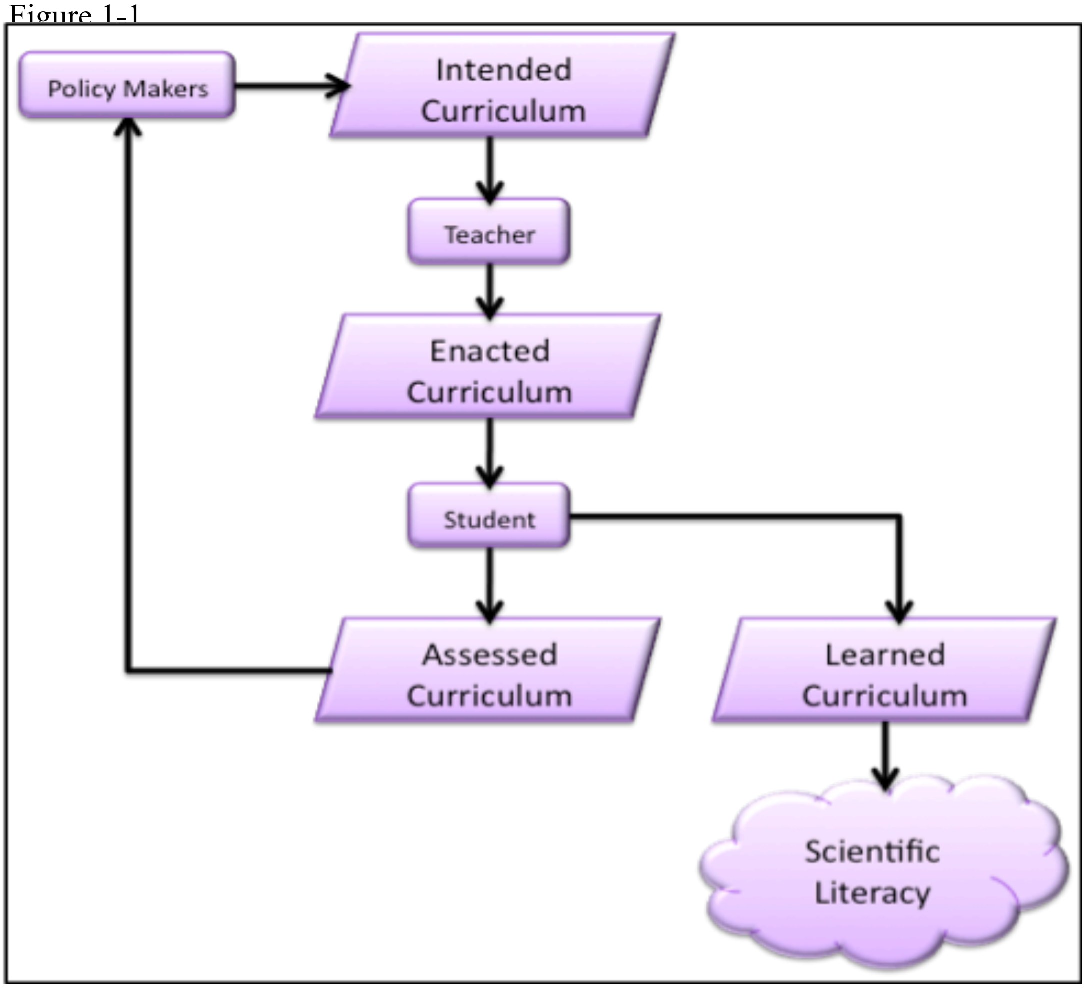
History and nature of science, in brief, encompasses what science is. Nature of science refers to what science is as a human endeavor, including the process of generating scientific knowledge and distinguishing scientific knowledge from other kinds of knowledge. It includes what sorts of questions science can answer, and what it means to think like a scientist (McComas, Clough and Almazroa 1998). The history of science gives a historical perspective on how the body of scientific knowledge has been accumulated, and how the process of doing science has changed over time (Russell 1981, Maienschein and Smith 2008). In this way, the history of science serves to give real examples that support ideas about the nature of science. By understanding the exploration of scientific knowledge, and how ideas have changed over time, students can get a feel for science's tentative nature.

In this thesis, I examine the permutations of this aspect of scientific literacy, the "history and nature of science," in US science education standards documents, from the national level to the state level. My goal is to understand how much credence education policy makers have given to the claim that history and nature of science is important. Assessing how well history and nature of science actually help students to become scientifically literate would require research far beyond the scope of this thesis. Thus I will not discuss textbooks, teacher education programs, individual classroom practice, or student assessments in any great detail, nor do I make the claim that any particular standards document's approach to the history and nature of science is the right one. This is only partially for the sake of simplicity; my approach also makes sense in light of the role that standards are supposed to play in the US education system.

Standards are one form of what sociologists of education call "**intended curriculum**"—that which students ought to learn. Originally, standards were meant to be a benchmarking aid, to evaluate whether or not students had achieved the education that society wanted for them. Over time, standards have come to be more like a curriculum framework instead. Standards are a type of policy document that set forth what it is we want students to have to learn and, at times, what we do not want them to learn. Thus the development of standards is a contentious process, and often the subject of local, state, and national debate. Science education consultant Lawrence Lerner puts it another way: "[Standards] are meant to serve as the frame to which everything else is attached, the desired outcome that drives countless other decisions about how best to attain it" (Lerner, Good Science, Bad Science 2000, ix).

Figure 1-1 shows a flow chart of a "standards-and-accountability"-based education system (based on Porter and Smithson 2001). In such a system, the intended curriculum, enacted curriculum, and assessed curriculum are aligned. In other words, what teachers actually teach and what students are tested on should accurately reflect the intended curriculum. In science education, the enacted curriculum should also lead to students actually becoming scientifically literate. In such an aligned education system, standards documents provide a clear statement of just what the intended curriculum is that ought to lead to student achievement (Gamoran 1996, Porter and Smithson 2001, Taking Science to

Figure 1-1



School 2007). But there are other sociological theories of the organizational structure of education systems. While idealized, normative standards-based reform would produce a curriculum that looks like the flow chart, descriptive sociological work indicates that real education systems are "loosely coupled" (Weick 1976, 3, Orton and Weick 1990).

A loosely coupled organization is one that is composed of people, institutions, and policies that influence each other in ways that are hard to disentangle. Factors that seem to be outside the organization's purview may have effects on the outcomes of a loosely coupled organization, e.g., the statistical correlation between student test scores and parental income (Goldhaber and

Brewer 1997, Finn, Julian and Petrilli 2006, Ravitch 2010). The recently released science scorecard from the 2009 National Assessment of Educational Progress lends credence to the “loosely-coupled” view. The report breaks down students’ scores into many fine-grained demographic categories. It indicates that there remains a significant inverse correlation between eligibility for free and reduced lunch—a commonly used indicator of poverty—and test scores. The NAEP also shows that a high level of parental education, though external to the educational system proper, is linked with high scores in science. In fact, only one correlation noted by the NAEP is actually related to the student’s own education in science: students who have taken biology, chemistry, and physics do much better on the assessment than students who have taken only biology and chemistry. Those who have taken only biology fare worst[1] (National Center for Education Statistics 2011).

In short, though some policy makers, journalists, and commentators are obsessed with developing more and better standards documents, there is little basis for the belief that creating exactly the right standards will reliably produce scientifically literate students. But understanding how the ‘history and nature of science’ has been interpreted over different phases of standards-based reform should tell us something about what policy-makers (and those who influence them) *think* students need to become scientifically literate. The acceptance and

[1] We might think of that result as curriculum that is insufficiently aligned to the assessment, since the NAEP science assessment tests for achievement in all subject areas.

integration of history and nature of science in standards indicates the degree to which it is taken seriously by the arbiters of educational reform.

In order to get a sense of how US science education policies have changed in regards to the history and nature of science, I have chosen to examine three phases of development. First, I review the history of science education in the US beginning at the turn of the twentieth century. Using the history of science to teach the nature of science is rooted in educational reform started prior to World War II. It is also instructive to see familiar current arguments about the proper goal of science education repeated by authors and reformers of many decades past. The historical narrative sets the stage for the beginning of standards based reform in science.

The second historical phase is the creation of voluntary national science standards. I look at two influential national groups, the American Association for the Advancement of Science (AAAS) Project 2061 and the National Research Council (NRC) National Committee on Science Education Standards and Assessment. Both of these projects resulted in publications that laid out a vision for science education standards during the mid-nineties, when standards-based reform was truly getting underway. Both projects placed heavy emphasis on the history of science and the nature of science as key components of scientific literacy. However, there were some important differences in how they used the history and nature of science, especially as regards other elements. Their differences play a significant though not comprehensive role in the drafting of state standards.

Following this, I conducted a survey of history and nature of science in state standards documents. In the interests of simplicity, I limited the investigative scope to the most recent high school standards for each state as of December 2009. From the results of this review, I developed four profiles to describe differing approaches to "history and nature of science." In brief, those profiles are 1) Inquiry and History & Nature of Science; 2) STS and History & Nature of Science; 3) History of Ideas; and 4) No History & Nature of Science. I explain these profiles further in chapter four. Then, with twelve states as examples, I use the profiles to compare and contrast the different choices about the place of history and nature of science that standards authors have to make. The four profiles serve as author-imposed categories that give structure to what would otherwise be an overwhelming amount of diversity.

American citizens, including those who work in the field, hold diverse opinions on the role of science education. Should its main goal be economic competitiveness, focused on the production of technology workers and future scientists? Should it be most concerned with preparing students for responsible civic engagement as a non-scientist? Should it be a fundamentally liberating exercise, something that both enriches and empowers our most underserved students? Should it just be fun? Perhaps it must be all of these things! Such ideological goals play a large role in educational reform strategies.

Standards documents are usually written by committees, and so they are sensitive to the difficulties that arise in creating consensus among heterogeneous viewpoints. The lack of clarity about meaning of "scientific literacy," explained above, is a response to the lack of agreement about the goal of science education in general. The vagueness allows policymakers to gloss over or avoid the points on which they do not agree. But it creates a problem when committees must decide how to incorporate things like history of science or philosophy of science into the curriculum. Following the concept “the history and nature of science” through the last two-and-a-half decades of standards-based reform reveals that there is a conceptual crisis in what scientific literacy is, and doubt as to whether it is even a good goal. What seemed to be a clear vision for history and nature of science at the beginning of the standards-based reform movement has since become murky and uncertain.

CHAPTER 2 A BRIEF HISTORY OF SCIENCE EDUCATION IN THE UNITED STATES

History provides touchstones to refer to during subsequent discussion of the events leading up to the creation of *Benchmarks for Science Literacy* and the *National Science Education Standards*. The relative importance paid to science facts versus the structure of science and its applications changes at various points in the history of science education. At some points, the "array of useful facts" that science provides was thought more important than the "habits of mind" that science instruction could develop. More generally, history demonstrates that science curriculum in the United States has been a battleground almost since the beginning of compulsory public education.

Before Standards – Early Reform Efforts

At the end of the nineteenth century, science education was not *de rigueur* in public school; the study of logic, rhetoric, geometry, and the classics were thought to teach young people all the necessary intellectual skills to take their places in society (DeBoer 1991). Faced with the established supremacy of a liberal arts education, public intellectuals such as Herbert Spencer and Thomas Huxley (among others) argued that education in the natural sciences would best develop good mental habits in students (DeBoer 1991, 8-9). Science education strengthened memory skills, which were thought to be very important. Education in the natural sciences would give students useful facts about the world. Science imparted the best methods for organizing and systematizing knowledge, leading to clarity of thought. Science also trained young people in the skills of inductive reasoning.

One of the earliest attempts to standardize education in the US occurred in 1892 with the meeting of the Committee of Ten. The leaders of ten prestigious learning institutions, including the President of Harvard University, gathered in order to create a set of entrance requirements for higher education. This meant setting down what curriculum must be taught in secondary school to those students who intended to go on to college. High school curriculum sequences in science, mathematics, history, and literature still show the influence of the Committee of Ten (DeBoer 1991).

The committee's science recommendations were issued in a report on physics, chemistry, and astronomy, and a report on natural history (botany, zoology, and physiology) (Report of the Committee of Ten 1894). Both focused heavily on the importance of experiential or laboratory work. The report on physics, chemistry, and astronomy suggested that students should learn "chiefly, but not exclusively, by means of" experimentation and laboratory work; the report on natural history similarly argued for the "absolute necessity of laboratory work." Students were also to keep a detailed lab notebook for each science course, which would train them in the "art of expression." In a section that deals heavily with how to apportion the limited amount of school time to all of the important subjects students must learn, the Committee of Ten's main report calls for 25% of instruction time to be devoted to laboratory courses in science.

The laboratory courses underwent subsequent reorganization in the early twentieth century, with some educators arguing for a curriculum organized around important and socially relevant issues (Hurd 1998). John Dewey argued that while science curriculum ought to be relevant to students' lives, the logical structure scientists themselves used should organize the content (Ready, Set, SCIENCE! 2007). Dewey's approach to science education deemphasized detailed content knowledge in favor of problem-solving and critical inquiry skills (Rudolph 2002, Taking Science to School 2007). Dewey's influence on the science curriculum during his lifetime (1859-1952) was primarily limited to the student teachers he educated at the University of Chicago Laboratory Schools. However, his legacy as an American pragmatist philosopher, contributing extensively to philosophy of science and education theory, has made his intellectual contributions very influential over the past century (DeBoer 1991, Rudolph 2002).

Meanwhile, Harvard President James B. Conant was fomenting revolution. According to his protégé Gerald Holton, Conant was troubled by the lack of scientific understanding the lawmakers and military officers around him possessed. The great historian of science George Sarton was one of Conant's early mentors, and his influence is obvious in the curriculum Conant created: The Harvard General Education. The science courses in this curriculum featured the development of science as part of Western culture (Holton 1999). Himself a trained chemist, Conant chose to teach one of the natural science courses, inaugurating what has come to be known as the Case History Method of science education (Allen 1970). Conant used historical episodes in science not only to introduce modern theory, but also as a way to teach students about the nature of science (Leite 2002, Russell 1981). The book *General Education in a Free Society: Report of the Harvard Committee*, published in 1945, elaborated on the need to include history of science education in the pre-college years in order to ensure that those who did not attend college could still benefit from a solid understanding of the "scientific worldview" (quoted in Holton 1999, S101).

Sputnik, the Cold War, and Curriculum Reform

But outside of Conant's (admittedly large) sphere of influence, the US's involvement in World War II and the subsequent Cold War captured the focus of efforts in science education. After WWII ended, hundreds of German scientists were imported to the US through the intelligence community's foreign scientist program Operation Paperclip.[2] But as the Cold War escalated with the launch of Sputnik in 1957, national security concerns translated to a new sense of the importance of science education (Rudolph 2002). The USSR was perceived as a powerhouse of scientific and technological innovation. To compete with the Soviets, the US would have to have more homegrown scientists and engineers (Raizen 1997).

Sputnik had a deep and lasting impact on science education in the US. Following its launch, a report delivered to President Eisenhower by the President's Science Advisory Committee (PSAC) instigated federal involvement in science education. Released in 1959, "Education for the Age of Science"

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[2] http://www.archives.gov/iwg/declassified-records/rg-330-defense-secretary/ (Accessed 5 Sep 2010)

emphasized a pragmatic national interest in cultivating future scientists (Briber 1959, Hurd, Science Literacy 1958, Hurd, Scientific Literacy: New Minds for a Changing World 1998, Wang 2008). Chiefly concerned with integrating modern theory in secondary science education, PSAC's report and the policies it produced gave rise to the curriculum reform movement (Shamos 1996, Rudolph 2002).

Paul DeHart Hurd, one of Eisenhower's science advisors, claims to have coined the phrase "science literacy" in Sputnik's wake (Hurd 1998). In his 1958 article "Science Literacy: Its Meaning for American Schools," Hurd cites the influence of scientific advances on the development of modern society, and (echoing Conant) bemoans its lack of treatment in elementary and secondary school. An education that instilled science literacy would encourage "the development of an appreciation of science as an intellectual achievement, as a procedure for exploration and discovery, and…illustrate the spirit of scientific endeavor" (15-16). Besides defining what science literacy ought to include, Hurd also asserts that the curriculum in textbooks is "spread thin over [too] many topics," and so work must be done to determine the most important things to teach—a concern that is still all too familiar to twenty-first century reformers.

The work that Hurd called for was realized in a period of reform that flourished between 1957 and 1964—referred to now as either the "NSF curriculum" or the "Alphabet Soup" curriculum due to the proliferation of acronyms. Most notable among the projects sponsored by the NSF were the Biological Sciences Curriculum Study (BSCS), the Physical Science Study Committee (PSSC), the Chemical Education Material Study (CHEM-STUDY), and the Earth Sciences Curriculum Study (ESCS) (Taking Science to School 2007, DeBoer 1991). Eschewing what they perceived to be anti-intellectual pedagogical practices of the time, the curriculum and courses they developed focused on discipline-specific content and laboratory skills (Hurd 1998, Rudolph 2002).

The reform was not enough. Due to dismal enrollment in high school physics courses, the NSF commissioned a second curriculum project in addition to the PSSC. Harvard Project Physics was lead by Gerald Holton, a physics professor at Harvard who was widely regarded as an excellent historian of science; F. James Rutherford, a high-school physics teacher enrolled in graduate study; and Fletcher Watson, a professor of education (Holton 1999). Project Physics was designed to be more humanistic than the PSSC products (Holton 1976). Its use of historical context, history of ideas, and the cultural aspects of science were markedly different from PSSC's fact- and skill-based content. The authors intended their curriculum to be more equitable and inclusive. Holton wrote in his 1976 explanation of the philosophy behind Project Physics that he could see "no reason why a student should be deprived of seeing the historical connections and present applications of physical science in his or her own country" (332). While the other curriculum reform focused on throwing detailed content at students, Project Physics was concerned with attracting students, making the science more interesting and relevant. Perhaps because of this, female students chose to take Project Physics more often than they did other physics courses when given the opportunity (Holton 1976).

The Era of Standards-Based Reform

The history of what we call "standards-based reform" began in the Reagan years. Gerald Holton, one of the creators of the Harvard Project Physics curriculum, recalls that in the first year of Ronald Reagan's presidency, the citizenry's interest in public education was "at a low ebb" (Holton 1984, 2). Appealing to his fiscal conservative base that wanted to cut federal spending, one of Reagan's campaign promises had been to abolish the Department of Education (Holton 1984, Shamos 1996). By 1981, the Department had already experienced significant cuts. The "Science Education Directorate," long a part of the National Science Foundation's charter and a significant source of funding for science education research, was due to be cut (Holton 1984). At the President's request, then-Secretary of Education Terrel Bell commissioned an investigative committee ("The National Commission on Excellence in Education") to provide data on student achievement in literacy, mathematics, and science. The makeup of the committee was noteworthy in the lack of educational research and policy expertise of its membership. Primary author Glenn Seaborg and commission member Gerald Holton both had previous experience with science curriculum reform—Seaborg had been the chairman of the CHEM-STUDY project, Holton of Project Physics—but the rest of the committee members were mostly administrators of education, former teachers, politicians, or business leaders (Winegar 1984, Holton 1984, Burdman 1997).

Nevertheless, the National Commission on Excellence would have profound effects on US education. The commission released a 1983 report called

“A Nation at Risk”: an alarming, martial call to action for educational reform. The report paid special attention to reading, math, and science skills. The commission argued that a steady decline in achievement, particularly in math and science, would lead to a steady decline in the US ability to produce science and technology workers. Almost as an echo of the Cold War at its height, the report linked science and technology education to the continuation of US dominance as an economic superpower.

“A Nation at Risk” was where the idea of standards-based reform began to coalesce. The commission insisted that the main problem in US education stemmed from a tendency of students, parents, and educators to be satisfied with a bare minimum of achievement. Their recommendations included the development of more rigorous standards in K-12 education. From the main report: “Our goal must be to develop the talents of all to their fullest. Attaining that goal requires that we expect and assist all students to work to the limits of their capabilities. We should expect schools to have genuinely high standards rather than minimum ones, and parents to support and encourage their children to make the most of their talent and abilities” (para. 3).

Copies of the report sold rapidly. The mission was quite handily accomplished: interest and focus on K-12 education rose in the public sphere. State governments, the federal government, and non-governmental organizations alike reacted.

The push for higher standards in education turned towards developing national-level policy by the early nineties. National organizations of teachers and professionals such as the National Council of Teachers of Mathematics and the National Science Teachers Association formed committees to provide recommendations and guidelines to design these curriculum standards. In 1989, the new administration of President George Bush Sr. established the National Educational Goals Panel (Tanner and Allen 2002, Labov 2006). The panel outlived Bush Sr.'s presidency, and during Bill Clinton's administration released a report entitled "Raising Standards for American Education: A Report to Congress, the Secretary of Education, the National Education Goals Panel, and the American People" (National Council on Education Standards and Testing 1992). This report explored the possibility of developing national education standards, pursuant to the recommendations of "A Nation at Risk" (Labov 2006).

The creation of a uniform national curriculum has been a volatile topic in the US, even though other countries have developed and used nationwide standardized curricula for some time. The creation of a uniform national curriculum has been a touchy, politically volatile topic in the US (Gamoran 1996, Isaacson 2009). Though pursued by the Department of Education under Clinton, federal standards have never been adopted (Labov 2006). The National Educational Goals Panel was disbanded during George Bush Jr's presidency by the congressional act known as "No Child Left Behind" (NCLB) in 2001 (Tanner and Allen 2002).

While most adults in the US are probably familiar with the testing and accountability requirements of NCLB, few may realize that the act requires states to develop local standards in reading, math, and starting in 2007, science (Labov

2006). It is those state standards to which students, teachers, and schools were to be held accountable—and NCLB tied funding dollars to student achievement. While walking back efforts to federalize education, NCLB drove forward standards-based reform. In 2001, only 36 states had science education standards; by 2006, all states did except Iowa (Lerner, Good Science, Bad Science 2000, Finn, Julian and Petrilli 2006). Standards documents for all school subjects flourished and proliferated. The earliest were developed by California in 1990, and several states have gone through one or two revisions.

However, when Arne Duncan was picked for Secretary of Education in Barack Obama's cabinet, the idea of federal education standards again seemed likely. As Superintendent of Chicago City Schools, Duncan had expressed support for adopting common national standards. And in April of 2009, he told TIME magazine, "I know that talking about standards can make people nervous, but the notion that we have 50 different goalposts is absolutely ridiculous" (Isaacson 2009, 2). Where James Conant, fifty years hence, had praised the "diversity in experimentation" afforded by such regional diversity, Duncan sees a dangerous "extreme variation" in expectations (Conant 1952, 463, Isaacson 2009).

The Obama administration has incentivized a second attempt at federal common standards with extra school funding. The *American Recovery and Reinvestment Act* (2009) set aside funds for a program called "Race to the Top." States have to compete for money for education in this program, by submitting grant-like proposals—and the proposals must include a commitment to adopt common national standards.[3] The Race to the Top program awards extra points for proposals geared towards improving science, technology, engineering and math education (referred to collectively as STEM education). In June of 2010, a consortium including the National Governor's Association unveiled the "Common Core State Standards" in English and Math. At the time of this writing, many states have officially adopted these standards.[4] The National Research Council's science education branch is in the process of creating a framework for the creation of common science standards. In July of 2010, a draft of the "Conceptual Framework for New Science Education Standards" was released for short public commentary period.[5] A final version is due in late spring of 2011, but it remains to be seen if this curriculum framework will gain nationwide acceptance.

Education policies like No Child Left Behind and Race to the Top affect science standards by encouraging (or discouraging) their creation and adoption. The perceived necessity of creating state standards or adopting common standards changes when funding for schools is on the line. That underscores that the choices that standards authors make about what content to include, and in what form, are a statement about what they think good science curriculum is. As we look at different approaches to the history and nature of science, we must bear this in mind.

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[3] Race to the Top Program Executive Summary, p.7. November, 2009. http://www2.ed.gov/programs/racetothetop/executive-summary.pdf

[4] http://www.corestandards.org

[5] The draft was on the web from about 12 July to 2 August, 2010. After that period, a copy could be obtained by emailing bose@nas.edu.

Standards for Science

Within the major contours of the history, some detail is required about the beginnings of the national level science frameworks. In science education, one of the most prolific of the early standards reform groups was Project 2061, an offshoot of the education arm of the American Association for the Advancement of Science (AAAS). Project 2061 was founded in 1985, the year of Halley's Comet's most recent pass by Earth. The auspicious year inspired the initiative's name; the comet will return in the year 2061. In a 1993 article, then-communications manager Shiela Harty encapsulated the project's lofty goal: "Those born when Project 2061 was launched, when Halley was last here, could be science literate senior citizens when Halley re-turns, able to understand the wonder of it all[6]" (Harty 1993, 506).

At its inception, the Director and Deputy Director of Project 2061 were F. James Rutherford and Andrew Ahlgren, who had both been members of the Harvard Project Physics curriculum—Rutherford as one of the three main editors[7] (Summary, Project 2061 1989, Holton 1999). The project was conceived with three phases: first the definition of what all students needed to know by graduation, then the development of tools and model curricula, and finally the gradual implementation of those curricula nationwide (Summary, Project 2061 1989, Harty 1993). The same year that the federal Educational Goal Panel's report

[6] Your author was four years old when Halley was last here. I remember it but vaguely, and will likely also vaguely recognize it upon its return, at the age of 80.

[7] Gerald Holton, the director of the Harvard Project Physics team, was not a member of the AAAS Project 2061 team, which fortunately left him free to comment on the work of Project 2061.

on national standards was released (1989), Project 2061 completed its Phase I with the publication of *Science For All Americans*, a book that summarized the knowledge that all Americans must have to be scientifically literate (Rutherford and Ahlgren 1989).

In 1993, Project 2061 released a mammoth book called *Benchmarks for Science Literacy*. *Benchmarks* was based on the knowledge requirements of *Science For All Americans*, and outlined what science content students ought to know by the end of second, fifth, eighth, and twelfth grade. Reflecting Project 2061's desire for greater integration among the various subjects taught in school, *Benchmarks* included standards for mathematics, technology, the social sciences, and history.

Aside from *Benchmarks for Science Literacy*, the other Phase II publications were *Blueprints for Reform* (1998), which synthesized studies and recommendations about systemic education reform (Holton 2002) and *Designs for Science Literacy* (2000), which provided models for science curriculum design. The two volumes of *Atlas of Science Literacy*, a set of concept maps that show which grade levels and sequences the ideas from *Benchmarks* should be taught, was published in 2001 and 2007.

Concurrent with Project 2061's work was the development and publication of *National Science Education Standards*. In 1991, the National Science Teachers Association (NSTA) requested that the National Research Council (NRC) develop standards for science education. The NSTA, whose own science standards project (Scope, Sequence, & Coordination or SS&C) had not been as well-received as Project 2061, hoped that the federally-backed NRC would be able to establish an authoritative consensus.[8] The NRC standards project was funded by the National Science Foundation and by the Board of Education. The AAAS, a professional society of scientists, could only suggest; recommendations from the NRC would carry greater weight. Together, they could form a consensus about recommendations for science standards from both the public and private spheres. Thus in 1996, the National Research Council of the National Academy of Science's released its national standardized curriculum in a book called *National Science Education Standards* (*NSES* hereafter).

The *NSES* and *Benchmarks for Science Literacy* have since become the defining science education texts. The framework for the 2009 National Assessment of Educational Progress refers to the two documents as "the best thinking in science instruction" only a paragraph before it asserts the importance of the history and nature of science (National Assessment Governing Board 2008, 123). But, best thinking though they may be, *Benchmarks* and *NSES* were published as guidelines—frameworks for states and local districts to use in drafting their own documents. No part of *Benchmarks* or *NSES* is compulsory, but the states have relied on them as the main sources for their standards.

[8] SSC was not a successful reform project, and was essentially defunct just a few years after its release. It is worth observing that the two groups that created the "successful" projects were primarily for scientists, and the science teachers' project was marginalized even by the government organization they sought help from. For a full discussion of the political issues involved, see Senta Raizen, "Standards for Science Education." (1997), 40. http://www.wcer.wisc.edu/archive/nise/publications/Occasional_Papers/RAIZEN/RaizenALL.pdf.

The degree to which *Benchmarks* and *NSES* agree on the inclusion of history and nature of science, then, has probably had a good deal of influence on the extent to which the states include it. Both documents were clear that the history of science and the nature of science are important aspects of scientific literacy, but do they include them in the same way? Do *Benchmarks* and *NSES* actually present an authoritative, consensus position, as the NSTA hoped they would?

CHAPTER 3 NATIONAL LEVEL STANDARDS

History of science and nature of science are present in both *Benchmarks* and *NSES*. They are not aligned in their coverage of them, however. While both texts talk about history of science, nature of science, and inquiry explicitly, only *NSES* categorizes “history and nature of science” as a unified content area. *Benchmarks* separates the two, and talks about inquiry as part of knowledge about the nature of science. History of science, or “historical perspectives,” is a content area of its own in *Benchmarks*; inquiry is a content area of its own in *NSES*.

How important is the organization of the documents? Does it matter that these categories are arranged differently between these two texts? While it may not matter for the individual teacher’s practice, it does matter at the intended curriculum level. The organization and arrangement of these content areas changes the implied and explicit reasons for including history and nature of science in the standards, and how they relate to other aspects of science instruction.

Table 3-1. A side-by-side comparison of the hierarchical organization of the relevant sections.

Benchmarks for Science Literacy (1993)	**National Science Education Standards (1996)**
<u>Ch. 1 The Nature of Science</u>	<u>Content Area A: Science as Inquiry</u>
• The Scientific World View	<u>Content Area G: History and Nature of Science</u>
• Scientific Inquiry	• Science as a Human Endeavor
• The Scientific Enterprise	• Nature of Scientific Knowledge
<u>Ch. 10 Historical Perspectives</u>	• Historical Perspectives

History and Nature of Science in *Benchmarks for Science Literacy* (1993)

Based on the 1989 book *Science for All Americans*, *Benchmarks* comprises twelve chapters, each further divided into sub-strands. Its first chapter is devoted the "Nature of Science," and the tenth chapter to "Historical Perspectives."

In the preface to the Nature of Science, the authors explain its importance: "Once people gain a good sense of how science operates—along with a basic inventory of key science concepts as a basis for learning more later—they can follow the science adventure story as it plays out during their lifetimes" (3). People who would become scientifically literate must be able to understand both the way science works, and the body of knowledge science has produced.

The Nature of Science contains three big ideas: The Scientific World View, Scientific Inquiry, and The Scientific Enterprise. The first section, The Scientific World View, is about the mindset scientists have in investigating nature. Scientists believe that there is a fundamental unity or rationality to the way the universe works, the text claims. By working together, humans can come to understand the universe and our place in it. This section also addresses the tentative nature of science. The text warns that these beliefs are very subtle, not dogmatic tenets to which all scientists are held. In the benchmarks for high school, the authors of *Benchmarks* discuss the benefit of history: "Aspects of the scientific world view can be illustrated in the upper grades both by the study of historical episodes in science and by reflecting on developments in current science" (8). Here, it refers explicitly to the use of case studies—see below in the discussion of the chapter on “Historical Perspectives.” But the things the students are supposed to know by the end of 12^{th} grade are the big ideas about the way scientists generally approach their work: knowledge is tentative, major shifts occur but rarely, and there is a fundamental unity in the way the universe works.

The section on “Scientific Inquiry” places heavy emphasis on understanding the nature of scientific investigation. In the preface, the authors raise the same concerns we have seen in the past (and still see currently) about school science laboratory experiences—they are most often a set of instructions that students follow, where the expected result is already given. Rather than doing such cookbook experiments in lab, students need to participate in scientific investigations that “more closely approximate good science” (9). *Benchmarks* suggests accomplishing this by decreasing the actual number of experiments performed, and stretching each experiment out over multiple sessions, giving students time to investigate and think deeply. The benchmarks for high school students revolve around understanding inquiry; the role of data, logic, and argument; the need for peer review; and the way new scientific knowledge becomes incorporated.

The final section in this chapter, “The Scientific Enterprise,” is about humans doing science for a living, and for the benefit of other humans. Some themes at the high school level are recognizable as STS (“Progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments” [19]). This section also includes benchmarks about scientific ethics, the role of scientists in the public sphere, and information about the disciplinary structure of science. There are also two benchmarks about history: the Egyptian, Greek, Chinese, Hindu, and Arabic contributions to the multi-millenial history of science, and the five-hundred-year-old European history of modern science traditions. In terms of the benefit to science literacy, *Benchmarks* holds that understanding the scientific enterprise will improve students' eventual civic engagement and will make them better potential scientists and technology workers.

The inclusion of history of science is apparent in most of Chapter 1, but *Benchmarks* also includes a chapter devoted to "Historical Perspectives." Chapter 10 outlines the objectives students should meet in understanding ten episodes[9] in the history of science. *Benchmarks*, quoting *Science For All Americans*, gives two reasons for why students should study the history of science. The first is that many of these episodes are part of our shared cultural heritage. The second is that history of science provides context and examples for understanding the nature of science. *Benchmarks* also points out that teaching students the history of science is pointless before they have grasped the content knowledge to be able to follow it. That is, the science content knowledge is pre-requisite to understanding the historical episodes deeply. The idea of "simplified versions" of the history is mentioned, but the authors do not recommend it (238).

The historical perspectives benchmarks, thus, are predominately placed at the high-school level. There are a few benchmarks at the middle school level, and

9 "Displacing the Earth from the Center of the Universe;" "Uniting the Heavens and Earth;" "Relating Matter & Energy and Time & Space;" "Extending Time;" "Moving the Continents;" "Understanding Fire;" "Splitting the Atom;" "Explaining the Diversity of Life;" "Discovering Germs;" "Harnessing Power."

only one episode, “Discovering Germs,” is heavily represented in these grades. In some places, the text emphasizes students’ grasp of the science concepts involved, introducing the benchmarks with each episode with what students’ ought to know or be familiar with. For example, in “Uniting the Heavens and Earth,” which is about Isaac Newton, the reader is told that “students should have encountered the relevant physical concepts and laws…prior to undertaking to learn the history associated with Newton” (242). In others, the connection between history and the nature of science is drawn out: “Apart from the story of Lavoisier…[the episode ‘Understanding Fire’] illustrates several aspects of the scientific endeavor” (249). In the chapter about Einstein and relativity, another possible reason to teach history of science shows up: “By treating [the concept of] relativity historically in high school, it is possible to avoid falling into the trap of trying to teach its technical and mathematical details” (244).

Project 2061 now maintains a free, public website for *Benchmarks for Science Literacy.*[10] The website includes content updates from the creation of *Atlas of Science Literacy, Volume 2* (2007). While the nature of science chapter of Benchmarks shows little change between the 1993 version and the up-to-date version presented online, the historical perspectives chapter shows quite a lot of change between the 1993 version and the current online version. The middle school benchmarks for Lavoisier, for example, originally contained one about alchemy; the new benchmarks contain two about phlogiston theory.

[10] http://www.project2061.org/publications/bsl/online/index.php (Accessed 10 Oct 2010)

History and Nature of Science in *National Science Education Standards* (1996)

There are eight content areas in *NSES*: A) Science as Inquiry; B) Physical Science; C) Life Science; D) Earth and Space Science; E) Science and Technology; F) Science in Personal and Social Perspectives; G) History and Nature of Science.

Content Area G (200-4) combines history of science and nature of science. There are three subareas at the high school level: "Science as a human endeavor," the "nature of scientific knowledge," and "historical perspectives." The first subarea, "Science as a Human Endeavor," covers information about people doing science. Students are to know that science can be done by individuals working mostly alone, or by people in complex collaborative groups, and anything in between. Science career options and science as a hobby (so-called "citizen science") should be discussed. The text also talks about the ethical traditions of science, such as peer review, truthful reporting, and making results public. Students should understand by the end of twelfth grade that science is an integral part of society and civic life.

The "Nature of Scientific Knowledge" covers the important understandings about what scientific knowledge is. Students should know that science is "different" from other processes of generating knowledge, in that it is empirical, logical, and skeptical. Students should also know that science has rules for evidence and that good scientific explanations can make accurate predictions about nature, and are based on consistent observations. Finally, the nature of scientific knowledge is tentative, and subject to change in light of evidence.

The third subarea, "Historical Perspectives," contains four big ideas that students should be able to grasp by the end of high school. The first is that modern science developed in Europe, but that non-European cultures have also developed science and used technology. The second is that most scientific progress occurs slowly, through daily work by scientists. This is followed by the idea that there have occasionally been big advances that "have important and long-lasting effects on science and society" (204). The text lists fifteen such advances by name[11]. The final point in this subarea is that "the historical perspective of scientific explanations demonstrates how scientific knowledge changes" over time.

NSES provides three main reasons for learning history of science. History gives context for understanding scientific inquiry, and shows that humans do science – putting the people back into the picture. History also illuminates how different cultures have used and been influenced by science. The authors include a lesson plan called "Analysis of Inquiry" in which students read primary sources, generally a past scientists' write-up of his or her experiments, and analyze the scientific inquiry that scientist used. This is geared towards helping students understand how humans go about doing science. Yet, though these history objectives are all geared towards contextualizing the nature of science, *NSES* cautions, "[l]ittle research has been reported on the use of history in teaching

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11 "Copernican Revolution"; "Newtonian Mechanics"; "Relativity"; "Geologic Time Scale"; "Plate Tectonics"; "Atomic Theory"; "Nuclear Physics"; "Biological Evolution"; "Germ Theory"; "Industrial Revolution"; "Molecular Biology"; "Information and Communication"; "Quantum Theory"; "Galactic Universe"; "Medical and Health Technology"

about the nature of science" (p 200). Since 1996, some research has been done (e.g., that by Kenneth Wilson and Constance Barsky, according to Gooday, et al. 2008), at least on college undergraduates, but there is still no wealth of empirical data.

Fuzzy Boundaries and Contested Territories

The respective authors of *Benchmarks* and *NSES* made different content and organizational choices about the history of science, nature of science, and scientific inquiry objectives. While many of the same ideas show up in each text, the structural differences of how those ideas relate to each other are profound.

Most obviously different is the two separate chapters that *Benchmarks* devotes to "The Nature of Science" and "Historical Perspectives," while *NSES* combines those areas into one section. The substantive content in regards to history of science illustrating the nature of science are very similar, because *Benchmarks* includes so many clear references to history in the "Nature of Science" chapter. The attention given to details about historical episodes in science is much greater in *Benchmarks* than in *NSES*, perhaps by virtue of having a whole chapter to themselves—though *NSES* actually includes a greater number of historical episodes in its standards.

According to *Benchmarks*'s structure, scientific inquiry falls under the umbrella of nature of science. The scientific inquiry objectives in *Benchmarks* are mainly about understanding how scientists conduct research. *NSES,* on the other hand, has scientific inquiry as stand-alone content, splitting it into understanding about inquiry and doing inquiry. Additionally, the hierarchical primacy that scientific inquiry has in *NSES* is probably indicative of its primacy in importance. Jane Maienschein, in a 2004 whitepaper entitled "Laboratories in Science Education," wrote that the standards in *NSES* mean for students to really engage in scientific inquiry, rather than in "appreciation from afar" (12). The closest to objectives about "doing inquiry" that *Benchmarks* comes is the final chapter of the book, "Habits of Mind," but the content therein is broad enough to apply to problem-solving and communication generally, rather than to just science.

The Content Standards of *NSES* includes an area with no clear analog in *Benchmarks*: Content Area F, "Science in Personal and Social Perspectives." Content Area F includes objectives about science and technology in society (STS), and understanding risk/benefit analysis, among other content. While *Benchmarks* has chapters that cover technology, human society, and the nature of science, it contains very little explicit coverage of the relationships among science, technology, and society.

The differences in content and organization could reflect different core aims of the two project committees. *Benchmarks* reflects the purposeful inclusiveness of the directors of Project 2061, in providing learning objectives for science content in disciplines that are traditionally outside the boundaries of the natural sciences: mathematics, technology, sociology and psychology, and history and philosophy (Raizen 1997, Harty 1993). *NSES*, on the other hand, is concerned with the "vertical" reform of science education. It provides learning objectives that are narrowly focused on the natural sciences, but has other chapters of standards for reforming science teaching practices, science teacher education, assessment creation, and the science education system at large.

These two works have been treated as mutually supporting, fully aligned, defining texts since the mid-nineties. *NSES* refers to *Benchmarks* and *Science for All Americans* in its introduction and calls the two texts "seminal work" (15). While *NSES* is the Department of Education-endorsed science standards text, its authors say that the content standards in *Benchmarks* "complies fully with the spirit" of those in *NSES* (15). Indeed, in both education journal articles and state standards, *NSES* and *Benchmarks* are often mentioned within sentences of each other.[12]

But while the education community and policy makers treat these documents as a unit, it is no secret that they differ in structure and organization. In a 1997 comparison paper, Senta Raizen pointed to a similar disjunction in the science content of the texts, specifically that only two of the chapters of *Benchmarks* actually deal with familiar school science content ("The Physical Setting" and "The Living World") and that *NSES* does not include as much detail about technology, mathematics, and social sciences (Raizen 1997, 13-14). Even authors who talk explicitly about the alignment of *Benchmarks* and *NSES* phrase the claim carefully. Tanner and Allen state that they are "aligned with each other in their approaches" to the creation of standards.

Are the differences in structure between *Benchmarks* and *NSES* merely formal, rather than substantive? Perhaps it does not matter that some ideas are

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[12] See for example McComas (1997); Donnelly and Sadler (2009); Bianchini and Kelly (2001).

grouped differently, so long as the content is roughly similar in both documents. Though experts have agreed in recent years that the traditional disciplinary boundaries in science are somewhat illusory,[13] we would certainly think it odd for content associated with biology to be presented alongside content associated with physics. Are the boundaries between inquiry, history and nature of science, and STS just fuzzy enough that the difference in categorization is unimportant? Or are these still contested areas, where the demarcation might be quite important, but still undefined?

More concretely, what effect might this fuzziness or lack of clarity have had on the state standards that were developed based on these two defining texts in science education? To begin to answer this question, we need a basic description of "history and nature of science" in the state standards. The section that follows summarizes my 2010 review of the state standards. While the diversity in the states' approaches to history and nature of science cannot be entirely explained by the misalignment of *Benchmarks* and *NSES*, there are clear patterns that do related to the fuzziness seen in these two texts.

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[13] See *Taking Science to School* 2007, 18, for a full discussion.

CHAPTER 4 REVIEW OF STATE STANDARDS

For most of the duration of standards-based reform, state governments have had jurisdiction for policy implementation. Standards in education have been enforced only at the state level. The very earliest state science education standards were created at the beginning of the standards-based reform era. By 2009, each state had created educational standards for science (and other subjects), and most states had revised their standards at least once. In science, most policy committees cite *Benchmarks* and *NSES* as the main sources of their frameworks,[14] and the standards tend to include a preface about scientific literacy.

A Camel is a Horse Designed by Committee: Creating State Standards

The process of creating standards varies from state to state. Generally speaking, standards are designed by committee[15]. The process of negotiation and consensus building can give odd outcomes. But, committees are an important part of democratic processes. We sometimes need to have complicated strategies made by a team of representative decision makers (Kirst, Anhalt and Marine 1997, 316). Committees are political bodies, and the interests and expertise of the committee members bears heavily on what content makes it into the final state standards.

[14] See Colorado, Florida, North Carolina for example – 32 cite both, 40 cite at least one, only ten cite neither.

[15] The title of this section alludes to an aphorism about design-by-committee that is most often attributed to Alec Issigonis, the designer of the Mini automobile. Sir Alec said, “A camel looks like a horse that has been designed by committee.”

There are different kinds of stakeholders in the educational process, and standards committees may be designed to include representatives of all stripes, or may be composed primarily of experts. The standards writing committee for the state of Georgia was made up of different kinds of science education experts: "K-12 Georgia science teachers, district science curriculum directors/supervisors, faculty professors from different colleges and universities in Georgia and…members of non-formal education institutions like the Georgia Aquarium, Zoo of Atlanta, [and] The Fernbank Museum of Science."[16] Active classroom science teachers were the primary authors of the Indiana standards (Jacobs 2006). However, in Massachusetts, business leaders played a lead role in the standards creation—both in instigating the process and in drafting the document (Jacobs 2006).

New Mexico is one of many examples in which the makeup of the committee creating the standards bears heavily on what content is included. Supporters of Intelligent Design reportedly "infiltrated" New Mexico's science standards revision process in 2003 by serving on the committee. According to an article in the *Reports of the National Center for Science Education*, three of the writing team members had joined the project with the intent of weakening evolution content (Berman, Johnson and Thomas 2003). The anti-evolution members only voiced their concerns at "nearly the end of the writing process," (10) by which time it would have been difficult to address their concerns according to the established review process. The organized action of pro-science

[16] Juan-Carlos Aguilar, Georgia Science Program Manager, in personal email to the author, 8 Feb 2011.

committee members enabled a narrow victory, but the outcome of the dispute was uncertain right up until the Board of Education voted to accept the standards with evolution. A similar occurrence in Kansas had the opposite outcome (Mead and Mates 2009).

Often, the process of writing the standards is fraught with controversy. California, which led the nation in standards adoption in 1990, set out to revise its standards for reading, math, science, and social studies in 1997 (Asimov 1998). The science standards project was embroiled in controversy before the writing even began (Bianchini and Kelly 2003). The subcommittee had solicited the help of potential consultants, who would lend their expertise to write the content, and had received two bids. One group, headed by Bonnie Brunkhorst, a science education professor at California State University-San Bernadino, made clear in their proposal that they intended to use *Benchmarks for Science Literacy* and *NSES* as a foundation (Jacobs 2006, 29). The second included three Nobel Laureates, including Glenn Seaborg who had been chief author of "A Nation at Risk" (Burdman 1997). The first group requested $178,000 for payroll and expenses; the other volunteered to work without pay, effectively bidding $0 . Protests arose when the subcommittee announced that it had chosen Brunkhorst's bid, only to later admit that it had broken its own point-based judging criteria and not given Seaborg's group credit for their zero-dollar price tag. Eventually the two groups chose to work together—a total of at least forty-eight scientists and thirty teachers—and created science standards that all could consent to, though some begrudgingly (Burdman 1997, Jacobs 2006, Asimov 1998).

As I conducted my review of state science standards, I was guided by three questions: Do the standards writers recognize the history and nature of science as an important component of scientific literacy? How do they interpret the differing guidelines of *Benchmarks* and *NSES* for the history and nature of science? Is there any clear consensus?

Methods

I reviewed the current (as of December 2009) high school science standards and curriculum frameworks for each state of the US. The state departments of education generally made these documents available on the Web. In some cases, the education departments offered documents beyond those that they label "standards"—supplemental components variously called "curriculum framework," "scope and sequence," or "syllabus[17]"—that specified in greater detail what should be taught. The distinction between standards and curriculum frameworks was not very clear in all cases, and so I included those supplemental texts when it seemed that they were playing the role of intended curriculum. In total, the DOE websites yielded in excess of 500 pages of material, though perhaps only a quarter of those required intense scrutiny[18].

I have not given grades or ranked states in my review, because my purpose is descriptive rather than normative. But perhaps because the metaphor of a report card lends itself so readily to education policy, many organizations

[17] E.g. Virginia, Pennsylvania, and Ohio, respectively.

[18] A good index to check is http://www.academicbenchmarks.com/ (Accessed 11 Nov 2010). This site lists standards for each state in a very clear, simple format. It is not my primary reference, because it does not include supplemental text like prefaces and appendices—hence important context is lost.

have bestowed grades on science curriculum standards. The normative work completed by those previous comparisons of state science standards provides context for the states I have chosen to describe in detail, by indicating that experts have found the standards to be good, bad, or mediocre. Such grades put pressure on policy makers to revise and update: few constituents want to see that their state received an "F" in something. I have summarized below the "report card" for the twelve states I will use as examples, along with a description of each report's object of analysis. These reports were instructive as indicators of what to pay attention to in reading and evaluating state standards.

The Thomas B. Fordham Foundation published report cards for state science standards in 1998 and 2005 (Finn, Julian and Petrilli 2006, Lerner 1998). In 2000, they published grades for each state's coverage of evolution (Lerner 2000). The National Center for Science Education published a 2009 follow-up report on evolution coverage, because some states had revised or newly adopted science standards (Mead and Mates 2009). Most recently, William F. McComas, a noted advocate of nature of science and a professor at the University of Arkansas College of Education, completed a review and ranking of state standards in regards to nature of science content (McComas, Lee and Sweeney 2010). These five reports were concerned with different aspects of science curriculum, and so their grades do not match up. While a very few states appear to have universal appeal, it is common for a state that the Fordham Foundation gave an A to received a D or F from McComas.

Table 4-1. Summary of State Standards "Report Cards" for Profiled States

	Lerner 1998 (Science Standards over all)	Gross et al. 2005 (science standards over all)	Finn et al. 2006 (all subjects)	Mead and Mates 2009 (evolution coverage)	McComas et al. 2010 (nature of science coverage
Alabama	D*	F	B-	F	D
Alaska	--*	F*	F*	F	B
Arizona	A*	B	B+	C	B
California	A	A	A	A	D
Georgia	D*	B	B+	C	B
Indiana	A*	A	A	A	A
New Mexico	F*	A	C-	A	B
Nevada	--*	D	C-	D	A
Mass.	C*	A†	A	B	B
Montana	--*	F	F	C	D
S. Carolina	D*	A	B-	A	F
Virginia	D*	A	B+	C	C

*** State has substantially revised document since this report**
† State has revised, but not substantially, since this report

Unlike McComas, Lee, and Sweeney in their review of nature of science content, I have not used a qualitative coding methodology. This should help explain why my resulting categories seem to contradict McComas et al.'s results at times—for example, I state that Massachusetts has no history and nature of science in its standards, while McComas et al. give the state an "A" for nature of science coverage. The coding methodology they employed does not distinguish content in Massachusetts's preface or appendices from the actual benchmarks. I am less interested in how many history and nature of science statements there are in the documents, or what percentage of the standards are about history and nature of science, than I am in describing the form and content of history and nature of science objectives. While Massachusetts's standards explain the importance of nature of science, the authors did not require that students be held accountable for it.

The first phase of my review was an informal read-through to become familiar with the material and with what standards generally looked like. This phase led to my decision to narrow the scope to high school standards only. The bulk of the history and nature of science objectives in state standards are articulated at the high school level, which matches up with the content of *Benchmarks* and *NSES.* Additionally, high school objectives, especially requirements at graduation, represent the science knowledge that we at minimum want young adults to have (given that twenty-first century Americans consider high school graduation a necessity).

Based on the initial review, I devised traits to look for in the standards (see table 4-2). I also recorded the date the standards were created, and whether or not *Benchmarks* and *NSES* were cited. I then read only the high school standards again, more closely, and kept a log of the text that I used to decide whether or not a state's standards exhibited the traits. Some revision and expansion of what I was looking for naturally occurred during this second perusal—for example, recording precisely which scientific theories were associated with history. My method was, in this way, similar to that of W. F. McComas and Joanne Olson's 1998 review of nature of science in international science standards—they also allowed their categories some flexibility at first, modifying their classification structure as they read, and devised generalizations based on the standards' content rather than creating a ranking (McComas and Olson 1998).

Table 4-1. Characteristics used in review of standards.

1) History and nature of science explicit, separate area	States that have this characteristic have a section in their standards document that lays out objectives for history and nature of science.
2) History and nature of science woven through content	States that included objectives for the history and nature of science in some form in their subject-matter content received a check for this characteristic.
3) History and nature of science standards integrated with Inquiry standards	Some documents included objectives about the history of science and/or the nature of science in the same section as objectives about science inquiry skills. Those states received a checkmark in this column.
4) History of science used separately from nature of science	A large number of states include some history of science objectives within the subject matter content, requiring that students learn how specific scientific knowledge was developed.
5) "Science as a Human Endeavor."	Because I so often found exactly this phrase in different states' documents, I logged whether or not it showed up. About half of the states make it an objective for students to learn about science as a human endeavor.
6) Science-Technology-Society relationships in standards.	States that require that students understand the relationships between science, technology, and society received a checkmark in this column.

Profiles of Standards

After compiling my data, I looked at the combination of traits for the various states and noticed some patterns of approaches to the history and nature of science. I organized four profiles from these patterns, which generalize the choices that standards committees make in regards to this area of science. The four profiles classify what I see as distinct modalities of "history and nature of science" content. States may use more than one of these approaches, but the approaches themselves represent choices that standards authors have to make in the inclusion of history and nature of science. Briefly, these choices are:

1) Whether to separate scientific inquiry objectives from history and nature of science objectives;
2) Whether to include objectives about the relationships between science, technology, and society;
3) Whether to use history of science to teach science content (rather than to teach nature of science) and;
4) Whether to include history and nature of science at all.

In regards to the structuring of history and nature of science and inquiry, there is an even split between states that separate the objectives in each category and states that combine the two categories, and about one-third of the states appear to have the two categories separate but still entangle the relevant ideas from one with another. The role of inquiry in science education has been a focus of educational reform for decades, as indicated in chapter two of this thesis. However, at least in the states' standards, its relationship to the history and nature of science is often muddled. Standards committees must decide whether objectives about inquiry are the same kind of thing as objectives about history and nature of science—and therefore belong in the same section—or not. To illuminate further what this means, I will compare the standards of Arizona, California, and Nevada.

There is also a fairly even split between states that include science, technology & society relationships (STS) and states that do not. Deciding to include STS or not is one choice. Deciding how history and nature of science relates to STS is another. The states that do use require STS benchmarks vary in whether or not their standards require STS as a means of conveying an aspect of the nature of science, or as a separate area of science literacy. To show what these choices look like in state standards, I will describe the documents of Indiana, New Mexico, and Alaska.

The choice to use some history for scientific content knowledge, i.e., the history of ideas, was very striking in how often it appeared in standards and how often it was for the same four theories. The Big Bang Theory, the Atomic Model, Evolution, and Cell Theory were the ones most commonly accompanied by historical objectives. There is also some regional quirkiness in regards to history for science content. Hawaii is the only state to include the history of Plate Tectonic Theory, for what may be obvious reasons. Florida expounds on the history of rocketry and space flight. Though most states include eponymous scientific laws like Newton's, Boyle's, and Mendel's, I did not count those objectives as historical unless the standards clearly asked for students to learn about their development. Both *Benchmarks* and *NSES* include a lot more historical episodes than the state standards tend to cover, so the choices to include these four as part of the content standards rather than in nature of science or cross-cutting process elements is noteworthy. The states described below for history of theories are Virginia, Alabama, and Georgia.

Finally, six states do not include any history and nature of science at all, or include only some history and no nature of science. Since there are so few states that make this particular choice, it is at least clear that the consensus to include the history and nature of science is strong. However, that decision does not seem to be the result of merely poor or “thin” standards. While the Fordham Foundation’s most recent grades for Montana, Alabama and Oklahoma standards were Fs, Massachusetts and South Carolina received As, and Maryland a B. I will use Montana, Massachusetts, and South Carolina’s standards as the examples for this profile.

The most definitive conclusion I can state about the approaches to history and nature of science by the states is that there is a distinct lack of consensus – no obviously preferred approach has emerged. Most states do include most of the ideas associated with the history and nature of science, but not all of them, and there is extreme variation in how those ideas are organized and how they are related to other ideas about doing science or applying science. The diversity represents different understandings of the role that history and nature of science can play in creating scientific literacy.

In the Fordham Foundation’s 2005 review, one criterion used was an evaluation of “Inquiry—or for *process* (‘*doing* science’), or history of science, or philosophy of science, or science-and-society, or some combination of these” (Gross 2005, 14). The Fordham Foundation is philosophically opposed to the use of constructivist pedagogy in science, stating that it is impossible for students to construct for themselves the entire scientific corpus through the use of “inquiry methods” (Gross 2005, Finn, Julian and Petrilli 2006). Their evaluation of “Inquiry” was primarily concerned with giving a low ranking to states that they felt espoused this teaching method too much. However, this description of what they think “Inquiry” means reveals that they consign history of science, philosophy of science, science and society, and scientific inquiry to one mish-mashed category. My review shows that they are not the only ones: writing teams are faced with trying to disentangle what "scientific inquiry" is from what "nature of science" is from what "science and society relationships'" are, and where history of science belongs.

Profile 1: Inquiry and the History and Nature of Science

The state of Arizona separates inquiry skills from the history and nature of science. The *Academic Content Standards* (2005) are organized into six strands, which are further subdivided into concepts and performance objectives. The first three strands are what the document calls "process and skills" content, and are 1) Inquiry Process, 2) History and Nature of Science, and 3) Science in Personal and Social Perspectives. The other three strands are disciplinary-specific content: Life Science, Physical Science, and Earth and Space Science. The preface to the 2005 document indicates that the process and skills strands are crosscutting skills that should apply to each subject. The Inquiry Process strand contains benchmarks mainly in doing science experiments. More reflective benchmarks are contained within the History and Nature of Science strand. In high school, the performance objectives require the big-picture stuff: students must understand that science is done by diverse cultures, and that science is driven by human curiosity to understand nature. STS benchmarks fall here, too: students must understand that science impacts society, and that society may "promote or hinder" science. Strand 2 also has objectives about peer review, ethics, rules of evidence, and open publication of science.

California’s *Science Content Standards* (1998) mixes only a very few history and nature of science objectives with content in doing and understanding inquiry. Most of the thirteen objectives for “Scientific Investigation and Experimentation” are about doing and understanding inquiry. For example:

> a. “Select and use appropriate tools and technology…”
> …
> d. “Formulate explanations by using logic and evidence.”
> …
> f. “Distinguish between hypothesis and theory as scientific terms.”
> …
> j. “Recognize the issues of statistical variability and the need for controlled tests.” (52)

Four objectives, however, contain ideas from the history and nature of science (objectives k-n). One such objective in this vein is “Recognize the cumulative nature of scientific evidence.” Such an understanding probably might require historical examples of one or many researchers conducting investigations over time, but none are specified. Another objective is even more clearly related to the history and nature of science: “n. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e.g., the Piltdown Man fossil or unidentified flying objects) and that the theory is sometimes wrong (e.g., the Ptolemaic model of the movement of the Sun, Moon, and planets)” (p 52). Thus, while California does not label the structure of its document to include history and nature of science as a content area, some relevant ideas are included, in an effort to extend students’ understanding of scientific inquiry and investigation.

The state of Nevada mixes history and nature of science with inquiry, but inversely from the state of California’s approach. The *Achievement Indicators for*

Science (2008) has four content areas: Nature of Science, Physical Science, Life Science, and Earth Science. In high school, the first area includes two "standards." The first is a focus on scientific communication: students in high school are supposed to know that scientists use data in making claims, that they use models, and that repeated experimentation is important. But this standard about communication also includes benchmarks about students safely conducting experiments. The second standard concerns students understanding science/technology impacts in terms of costs/benefits to society (STS). It contains a statement about the cumulative nature of scientific knowledge and understanding the development of new evidence.

Profile 2: STS and Nature of Science

New Mexico has robust coverage of STS relationships, which includes objectives about the history and nature of science. In the *Science Content Standards, Benchmarks, and Performance Standards* (2003), "Science and Society" is one of the three top-level content standards ("Strand III"). The other two areas are "Scientific Thinking and Practice" (encompassing doing inquiry, understanding inquiry, and using mathematical tools) and "Content of Science" (covering physical, life, and earth and space science). The Science and Society strand appears hierarchically equal in imminence to content knowledge and process skills, though there is only one main "benchmark" at the high school level: "Examine and analyze how scientific discoveries and their applications affect the world, and explain how societies influence scientific investigations and applications" (13). The benchmark covers nineteen "performance standards," including considerations of historical developments in science and technology, the use of science to inform policy decisions, and the ability to distinguish between real technology and fictional technology.

The *Science Academic Standards* (2000) for the State of Indiana seem to be based mainly on *Benchmarks for Science Literacy*, and like *Benchmarks*, Indiana's standards do not explicitly include objectives covering STS relationships. "Historical perspectives" are included in all grade levels. Indiana's standards cover "The Nature of Science and Technology" as a content area in K-8 only—by high school, students' previously acquired mastery of nature of science should support their learning. High school content is by discipline (Earth Sciences, Biology, Chemistry, Physics), with each divided into two strands: discipline-specific knowledge and relevant historical episodes. Indiana's inclusion of historical episodes is the most expansive of all states' frameworks. Their stated rationale for including history focuses on the tentative and cumulative nature of science—a near verbatim quote from the introduction to "Historical Perspectives" in *Science for All Americans*. "Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators" (Indiana *Science Academic Standards,* Teacher Edition 2000, 51).

In 2008, Indiana introduced the *Core Standards*, a supplement to the

Academic Standards and Resources of 2000. It is a slimmer document, and groups the "fine grain-size" objectives of the *Academic Standards* into seven or eight big ideas per grade level. The *Core Standards* do not replace the *Academic Standards*—merely restructures its content. The line numbers of the clustered objectives are listed underneath the Core Standard to which they apply. Yet, there seems to be confusion regarding which objectives from the *Academic Standards* belong with the "big idea" of Nature of Science: for the high school subjects, that is marked as "forthcoming." Line numbers belonging to historical perspectives are scattered among the Core Standards in each subject, not included under Nature of Science. The framers of the Indiana science standards do not recognize a connection between history and nature of science, despite having quoted *Science for All Americans* on the subject.

While Indiana looks more like *Benchmarks,* the science *Content and Performance Standards for Alaska Students* (2006) follows the outline of the content standards in *NSES*. There are seven content areas (A-G) including one for "Science and Technology" (Content Area E) and for "Cultural, Social, Personal Perspectives and Science" (Content Area F). The student objectives within these areas are arranged differently than the ones laid out in *NSES*. For example, in *NSES*, Content Area F includes the "science and technology in society" objective, while Alaska's standards make "understanding relationships among science, technology and society" the main objective of Content Area E.

Alaska has a very large and historically underserved Native population, which has succeeded in recent years in lobbying for education that is respectful and inclusive of their culture (Barnhardt, Kawagley and Hill 2000). Perhaps because of this, Alaska is the only state that has adopted cultural standards in addition to the academic content standards. The authors of Alaska's standards cared deeply about relating science education to cultural education. Both the "Science as Inquiry" and "Science and Technology" sections have objectives related to cultural influence on science and vice versa. Content Area F is entirely about science and culture, and understanding science as one way among many that cultures may use to understand the world. Content Area G, "History and Nature of Science," which includes the common ideas of the tentativeness of scientific knowledge and its cumulative character, also includes objectives regarding the influence of cultural perspectives.

Profile 3: History of Theories for Science Content

The Virginia *Science Standards of Learning* (2003) covers four core subjects in high school: Earth and space science, biology, chemistry, and physics. History of science appears throughout the subject matter. Biology includes the most objectives about history, with a whole section devoted to the history of biological thought--including cell theory, evolution, germ theory, the structure of DNA, and "collaborative efforts of science, past and present." Earth science contains a benchmark about the history and contributions of the space program, and chemistry one about historical atomic models.

These are all discrete bits of history that pertain directly to the theory that students would be learning concurrently, but there are a few examples of history benchmarks that would illuminate the nature of science. For example, in Physics, within a section about understanding scientific reasoning, students are asked to do an "examination of how new discoveries result in modification of existing theories or establishment of new paradigms." History of science is divorced from nature of science in the Virginia standards; the approach to nature of science content is a mix of inquiry (doing experiments) and reflecting on how science works. At the time of writing, Virginia's standards are in revision. Some of the subject-matter benchmarks are slated to move to the state Curriculum Framework, which lays out the sequence of specific content to be taught. The most recently released draft, from January 14, 2010, show that the benchmarks pertaining to the history of ideas remain in the standards. Yet in biology, the section previously devoted to the history of biological thought, "BIO.2," is to be broken up, and each historical item will be listed under the theory it relates to. For example, the "development of the structural model of DNA" will fall under BIO.5, the section about inheritance and protein synthesis.

By comparison, The Alabama *Course of Study: Science* (2005) has no mention of nature of science, and very little about inquiry. Attention is paid to "process and skills" in the conceptual framework, i.e. the doing-inquiry skills: "observing, communicating, classifying, measuring, predicting, inferring, controlling variables," etc. There are no benchmarks about STS relationships. Yet, as in Virginia, history of science is sprinkled throughout the subject matter content. Specifically, Alabama students are required to learn the history of the atomic model and of cell theory, including important scientists and key experiments. In addition, notes to the teacher say that the history of diverse cultures contributing to science makes science more inclusive for students ("General Introduction," 9).

Georgia is one of five states that require history for only one theory: evolution by natural selection. The *Georgia Performance Standards* (2006) benchmark SB5 reads, "Students will evaluate the role of natural selection in the development of the theory of evolution." This benchmark has five performance standards, but the first one is for students to "trace the history of the theory." No similar exploration of the history of any other theory appears in any other subject; only evolution gets this special focus. Unlike Alabama, the Georgia standards do include "Co-Requisite" standards (implying that they support the content standards) for the nature of science and for habits of mind. Georgia's prefatory materials cite and quote extensively *Benchmarks for Science Literacy*, and their structure more closely adheres to that text than to *NSES*.

Profile 4: History of…? Nature of…? Just the Science

Some states include very little history and nature of science, and some include none at all. The *Massachusetts Science and Technology/Engineering Framework* (2001) includes only subject-specific content in its actual benchmarks, i.e. "Earth and Space Science," "Life Science," "Physical Sciences," and "Technology/Engineering." Technically, then, students are only responsible for learning science content, and not responsible for understanding the nature of scientific knowledge, the history of science, the process of inquiry, or the relationships among science/technology and society.

However, the front matter of the *Framework* includes a section detailing the purpose of science education. Within this introductory section, the authors explain in broad strokes the nature of science, technology, and engineering. The next section covers scientific inquiry and experimentation and insists that while inquiry skills should not be tested as "stand-alone skills," teachers should give students lots of opportunities to do inquiry and experiments. History and social studies of science are covered in Appendix V, as an optional unit that should be undertaken with a history teacher's cooperation. In this, Massachusetts is aligned with the recommendation of historian Garland Allen, who wrote in "Intellectual History as an Organizing Principle" that history of science ought to be taught by a historian rather than a scientist, but that it would be most beneficial for a "modern theory" course to be taught alongside the history course.

The Montana *Essential Learning Expectations for Science* (2009) has six content areas that span the grades. They roughly correspond to the seven areas of *NSES*. Yet it is not immediately obvious that Montana does include nature of science in its standards. This is because the ideas that comprise nature of science instruction are included in the sixth content area, which requires that "Students understand historical developments in science and technology" (16). The "science and technology" and "history and nature of science" areas from *NSES* are rolled into one. The ideas associated with nature of science are there, but inseparable from historical and societal ideas, and not explicitly marked out.

South Carolina, on the other hand, resolutely pays no attention to history of science or nature of science. While the *Science Academic Standards* (2005) has an area for "scientific inquiry" within each discipline's benchmarks, covering all the key aspects of doing inquiry, there are no benchmarks for reflection on what science is. In several of the areas where other states (Approach D) insert some history of ideas, South Carolina's state clearly that history of science is not essential. For example, in biology, "It is not essential for students to…recall the historical development of the theory of evolution" (B-5). Benchmarks about STS are also rare; the lone societal consideration involves the application of nuclear science to power, because "South Carolina is a major player in the United States nuclear program."

Summary

The importance of including the history and nature of science seems to have been taken up by the states. But there is definitely not a consensus among the states about the relationship of history and nature of science with inquiry and STS. Nor is there even a consensus that the history of science is a necessary, complementary accompaniment to curriculum in the nature of science. It is here that we can most clearly see the influence of the difference between *NSES* and *Benchmarks*. Those states that rely most on Project 2061 are more likely to separate nature of science and history of science, while states that rely on *NSES* are more likely to keep them together.

Not all of the dissonance can be traced to that source, however. Neither *NSES* nor *Benchmarks* contained such emphasis on the relationships between science, technology, and society as many of the states do. Yet STS is a heavy focus in nearly half of the states. In some states, science and society content is presented as part and parcel of the nature of science. My review did not reveal the reason or source for such a focus. It would be a valuable future project to interview committee members, to track down meeting minutes, or even to look at the revision history of some states standards, in order to understand where this content came from and why.

Only a few states do not include the history and nature of science in some recognizable form. Very few are as deliberate and purposeful about excluding history of science and the nature of science as South Carolina. The South Carolina standards authors provide a statement about scientific literacy in their preface. More accurately, they give a statement about what scientific literacy is *not*: "Science goes well beyond simple recognition and the memorization of facts that many people mistake for scientific literacy. Therefore, many of the main verbs in the indicators of the South Carolina science standards reflect the cognitive processes described in the revised Bloom's taxonomy under the category understand" (108). The way that South Carolina's standards authors interpret scientific literacy does not include the history and nature of science; it only involves understanding science in some way that is more sophisticated than knowing science facts. There is no obvious indication why the state of South Carolina has such a narrow definition of scientific literacy.

Also unclear from this review is why some states include the history of science as part of discipline-specific content. As mentioned above, Indiana uses history of science according to the recommendations of *Benchmarks for Science Literacy*, which accords history value primarily for the transmission of cultural heritage. It is more difficult to determine why states such as Alabama require the history of just a few theories as part of the benchmarks for learning the modern versions. In some cases, such as Georgia's use of history only for biological evolution, it is tempting to suspect reasons for the inclusion. Perhaps the history of evolution is included to counteract creationist ideology? Or perhaps both proponents of evolutionary biology and of creationism believe that Darwin's story serves their agenda? Determining the cause would require a more detailed investigation. There is certainly precedence for teaching the history of some theories that dates back to James B. Conant's case history method in the forties. In some cases, perhaps, the use of history of theories may simply be tradition.

On a personal note, performing the state standards review enhanced my understanding of the relationship of scientific inquiry and science-and-society to the history and nature of science. Based on the material I had read in preparation for the review, and based on my familiarity with the Arizona science standards, I had conceived of these categories as quite distinct from each other. Thus, I did not expect to find that so many states include doing inquiry with nature of science. What I had come to think of as skill-based activities were often placed alongside reflective observations about the nature of science. The states combine and separate inquiry, STS, history of science, and nature of science in a variety of ways. After further reading and introspection, I realized that my pre-review conception that the history of science would be used primarily as a tool to illuminate the nature of science was not a unanimous, consensus position. Rather, it is one among many common interpretations of the role of history and nature of science in achieving scientific literacy.

CHAPTER 5 DISCUSSION AND CONCLUSION

The Role of History and Nature of Science

The goals of education are thought to reflect the kind of future citizenry that the present citizenry desires. In deciding what education should do, we are deciding what kind of adults we are trying to prepare students to be. But Americans do not actually agree in these matters. For this reason, the concept of "scientific literacy" has served well as a goal that everyone agrees is good to pursue. How can anyone be against scientific literacy? Scientific literacy just means "good science education." Because the concept has many facets and is so broadly defined (especially in *Science for All Americans*), people need not agree on specific outcomes. Still, since the mid-90s release of *Benchmarks for Science Literacy* and *The National Science Education Standards,* the history of science and the nature of science have been regarded as major threads of scientific literacy.

The Myth of Scientific Literacy is the title of a book published in 1996 by Morris Shamos, a physicist and sharp critic of the standards-based reform movement in science education. Shamos's central claim is that we cannot mean by "scientific literacy" what it seems we mean: a program of pre-college science education that will adequately prepare future scientists for college work while giving non-scientists the education necessary to be responsible citizens. The consequence of Shamos's argument is that if the concept of scientific literacy means something concrete and specific, it cannot be a goal that we would want for all students.

It seems that the future non-scientists would be future something-elses, and would, in Shamos's view, need to be adequately prepared during high school for their careers. Shamos is proposing a kind of career tracking that other nations explicitly engage in, but that Americans are generally uncomfortable with. However, *de facto* career tracking[19] is practiced in the United States, with varying amounts of transparency, and is often the result of systemic inequality.

The term "science literacy" was coined in 1958, a year after Sputnik's launch, and four years after the US Supreme Court decision in *Brown v. Board of Education of Topeka* ordered school desegregation. Coming as it does during a period of extreme inequity in America's school systems, Paul DeHart Hurd's "science literacy" at least seems to be meant for all students. The AAAS's Project 2061 certainly meant to take up the challenge of a science education that would benefit both scientists and non-scientists. *Science for All Americans* could not be more clearly titled. Its authors assert that a "well-designed curriculum" will be able to accommodate the "extra" needs of any student, while ensuring that no student fails to receive a solid education that leads to scientific literacy.

Still, it is not hard to detect a strain of division into future scientists and non-scientists in Benchmarks for Science Literacy. The chapter on the nature of science states that scientifically literate adults can "follow the science adventure

[19] An excellent example can be found in Jonathan Kozol's *The Shame of the Nation* (2005), pages 179-83, in which students who would like to take higher math and science courses describe being shuttled into hair-dressing and sewing courses at Fremont High School in Los Angeles.

story" as it plays out in their lifetimes[20]. Following a story is not the same as participating in the development of science. The goal of high school education probably should not be for all citizens to become scientists—surely some of them must become historians and philosophers of science!—but the sense of exclusion of these scientifically literate adults from being part of the science adventure story is troubling.

In some of the most recent science education reform work, the phrase "scientific literacy" is replaced with "scientific proficiency." Some of these texts argue, explicitly or implicitly, that scientific literacy is a fine goal, but does not translate adequately to college- and career-readiness (NRC *Taking Science to School* 2007, NRC *Ready, Set, SCIENCE!* 2007, The College Board 2009). On July 12, 2010[21], the National Research Council Board on Science Education (BOSE) released a draft for public comment of "A Conceptual Framework for Science Education" (Draft Framework hereafter). This Draft Framework, intended to replace *NSES* and serve as the basis of voluntary national standards, also speaks of scientific proficiency rather than scientific literacy.

The Draft Framework shows a hazy vision of what science standards may look like in the future. As in some of the current state standards, STS has a much broader role than in the reform projects of the 90s. But surprisingly, at least to this author, the Draft Framework drops all reference to "inquiry," explicitly replacing

[20] Previously quoted in chapter three of this text.

[21] As of April 2011, it remains to be seen whether the NRC's new conceptual framework will have the kind of lasting impact that *Benchmarks* and *NSES* have, or if it will descend into obscurity like the NSTA's Scope, Sequence, and Coordination.

the term with "practices of science." The history of science is retained only as a small part of "Science, Technology, Engineering, and Society." Nature of science is barely mentioned.

The shift from scientific literacy to scientific proficiency is accompanied by a reduced role for history and nature of science. But it is not clear that the term "scientific proficiency" means something very different than "scientific literacy." The denotation of both terms is merely "educated in science." Both terms can operate as a way people can agree on the broad strokes of what science education should do, while still disagreeing on the particulars. It would likely take another Master's thesis to try to understand the arguments behind why this particular shift has taken place, including why it seems to mean moving away from history and nature of science. For now, it is enough to underscore that there has been no consensus on the role of history and nature of science, and if the Draft Framework is any indication, there is no consensus forthcoming.

Where does this leave the history and nature of science in continued standards-based reform? Will it persist in revisions of science standards in various forms? Will it be subsumed under the umbrella of science, technology, engineering and society, as it was in the Draft Framework? Will it come to be excluded from the standards as in South Carolina, or made optional as in Massachusetts?

The history of science education discussed in chapter 2 reveals the antecedents of "history and nature of science" education. Conant's case history method of science might have taken even greater hold in universities across the

US, perhaps even percolating down to high schools, were it not for the urgency of the Cold War. In the pressing need to develop future science workers, the NSF curriculum projects left a humanities-inclusive view of science behind. *Harvard Project Physics* was Gerald Holton, F. James Rutherford, and Andrew Ahlgren's attempt to revive the historical method.

Rutherford and Ahlgren's experience with *Project Physics* may have been part of the reason that their later work with *Benchmarks for Science Literacy* included historical perspectives and the nature of science. However, *National Science Education Standards* used the history of science and nature of science in their standards, as well. That both of the big national science projects incorporated these general themes shows that there was momentum in the nineties behind a humanist science instruction. Yet the two projects did not fully agree on how that instruction should take shape. Unfortunately, *Benchmarks* and *NSES* were the guiding lights that state standards committees had to steer by. Where they do not agree, state writing teams had to make choices.

Those choices have yielded different results across the states. The four Profiles discussed above reveal the conceptual messiness of STS, inquiry, history of science, and nature of science—at least so far as education policy is concerned. When committees sit down to write standards, they need to be able to put ideas into neat categories that can be aligned with state assessment frameworks and curriculum requirements. Julie Bianchini and Gregory Kelly describe a similar urging for formal neatness in a 2003 essay about textbook adoption in California. Members of the textbook committee, they write, were not pleased that there was no single definition of "hypothesis"—and even less pleased to be informed that many scientists do not use hypotheses. Perhaps it should not be surprising, then, that a few states have chosen to leave history and nature of science out entirely.

We may not need to be too worried that the standards for science will be written such that they will actually preclude students from learning or achieving highly in science. As the 2009 NAEP report suggests, much more goes into a child's academic success than the curriculum standards under which they are educated. Even if history and nature of science were removed from the standards, it would not *per se* prevent teachers from deciding to use them. It would, however, indicate a decision by policy makers that the goals of science education in the United States are not commensurable with the perceived outcomes of an education in the history and nature of science. Whatever they think that history and nature of science is selling, they are not buying.

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