Networks of Power and Privilege: A Critical Discourse Analysis of the US Next Generation Science Standards

by

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Abstract

Science holds significant power in shaping many of our everyday choices. Thus, it is important for science education to foster the development of scientific literacy for all students, so that they can navigate science-related issues in their daily lives. This study carries out a critical discourse analysis of the US Next Generation Science Standards (NGSS) through an actor network theory framework to explore how the NGSS document is shaping the discourse of science education. The findings of this study show that the NGSS delivers a highly technocratic document that leaves little room for democratic engagement. It seems to place an emphasis on science education that is necessary for entry into STEM fields. The NGSS appears to have co-opted the notion of a “science for all” approach to push a neoliberal agenda of science education that serves to fuel the economic market and privileges a select few.
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Chapter 1
Introduction

The Sputnik Moment

On October 4, 1957, the Russian satellite Sputnik was launched into space. It marked a period of fear and paranoia that the United States was losing the “Space Race” (Rutherford, 1997). This concern ignited a revolution in science education. The federal government, led by President Dwight Eisenhower, invested more than a billion dollars to rejuvenate the science curriculum under the National Defense Education Act (NDEA) that passed on September 2, 1958 (Bybee, 1997). The act aimed to, “To strengthen the national defense and to encourage and assist in the expansion and improvement of educational programs to meet critical national needs; and for other purposes” (NDEA, 1958). It was as a major act of reform and marked the beginning of federal involvement in education. The purpose of the NDEA was to strengthen the education system at all levels and to encourage students to pursue higher education. There were special provisions, such as scholarships and grants, for programs in science, mathematics and modern foreign languages. This began a domino effect of science initiatives within the US, including the founding of the National Aeronautics and Space Administration (NASA) in 1958 to advance the American space program. With the influx of funding, federal agencies, particularly the National Science Foundation (NSF) provided increased support for the development of new science and mathematics programs.
Over the next few decades, several national reports and guidelines aimed to promote scientific literacy. The importance of being literate in science was touted as a national goal for all students. In 1996, the National Research Council released the *National Science Education Standards (NSES)*. While it was an advisory document of guidelines for K-12 science education, it had significant impact in governing state science curriculum and assessment. It became a benchmark for state-level and national achievements in science education and promoted a greater dependence on standardized testing (DeBoer, 2000).

The reaction to Sputnik supported the rhetoric of a crisis within the US education system. This led to initiatives, such as the NDEA, in which federal involvement coupled national educational policy with national needs for innovation and defense (Hunt, 2010).

Federal involvement, or intrusion as some might say, in shaping science education within the United States continues today. In November 2009, President Barack Obama launched the *Educate to Innovate* campaign, a nationwide effort to increase student achievement in math and science by committing to an improvement in Science, Technology, Engineering and Mathematic (STEM) education. In launching the campaign, President Obama cited the need for a STEM workforce to address the challenges of the 21st century. He identified three major priorities of STEM education: improve STEM literacy for all students, encourage students to pursue careers within a STEM workforce, and expand STEM education and career opportunities for underrepresented groups, such as women and minorities (The White House, 2009). In order to bolster this campaign, the federal administration set aside $4.35 billion in 2009.
for the Race to the Top (RTTT) – a school grant program that ensured competitive preference to states that aimed to improve STEM education (Johnson, 2012). In 2015, the US federal government has proposed a budget of close to $3 billion to fund federal education programs that enhance STEM education at all levels (U.S. Department of Education, 2014).

The rhetoric of a crisis in science education continues to be invoked today on the national level, while initiatives such as *Education to Innovate* that increase STEM education are proposed as solutions. In his 2011 State of the Union Speech, President Obama proclaimed:

“This is our generation’s Sputnik moment. Two years ago, I said that we needed to reach a level of research and development we haven’t seen since the height of the Space Race. And in a few weeks, I will be sending a budget to Congress that helps us meet that goal. We’ll invest in biomedical research, information technology, and especially clean energy technology -- an investment that will strengthen our security, protect our planet, and create countless new jobs for our people.”

**Statement of the Problem**

One of the aims of the STEM movement is identifying students who may pursue careers in STEM fields. This appears to have become a significant driving force in current US science education reforms as national reports cite the need for a STEM workforce (NRC, 2011). It seems to be motivated by the notion that investments in STEM fields are fundamental for economic and social development in modern society (NRC, 2011).
The National Research Council (NRC) in the US has stated that the future economy will be driven by scientific and engineering innovation. It has predicted that the nation’s workforce of scientists and engineers, comprising 4% of the population, will disproportionately create jobs for the other 96% (NRC, 2011, p. 3). Therefore, declining interests in STEM fields, as highlighted particularly by policy-makers in the US, is considered a threat to the nation’s progress, including its ability to harness technology for military purposes (Machi, 2009). It is not surprising then that there has been significant investment of resources for the STEM movement in the US in their effort to maintain economic competitiveness (Steele, Brew & Beatty, 2012).

The coupling of education and national economic interests is not novel, as highlighted through the major reform efforts of the NDEA. In fact, subsequent major educational initiatives within the US (which will be discussed in Chapter 2) since that time have reiterated a crisis within science education. It has resulted in the development of more rigorous academic curricula in an effort to better equip the nation for global participation (Laukgsch, 1999). Consequently, the purpose of science education appears to have shifted towards increasing the number of scientists and scientifically skilled workers in order to remain globally competitive. This shift has created a disproportionate population of scientifically illiterate citizens who are not knowledgeable about the science and technology that affects their daily lives. Instead, they have become largely reliant on experts in navigating science-related issues (Roth & Calabrese Barton, 2004). The current STEM movement has seemingly rejuvenated this shift in science education.
Science education has become a powerful commodity in many societies. The narrow scope of STEM education continues to marginalize students who choose not to pursue science post-high school but still need it to function in our scientifically inclined society. Moreover, several scholars have noted that STEM initiatives fail to address the broader sociocultural and political needs of global communities (Zeidler, 2014). Therefore, these initiatives seemingly privilege the knowledge needed by a select few, and in doing so, they create barriers for the education of a democratic citizenry (Giroux & McLaren, 1986).

With these concerns in mind, this study examines how current science education reforms in the United States, spurred on by the STEM movement, are shaping the discourse of science literacy. A parallel project of the STEM movement in the US is the recently released Next Generation Science Standards (NGSS) – the revised national science education standards. The document, released in 2013, outlines the necessary content and skills required to be proficient in STEM fields across all science disciplines and grades. Thus, this study has chosen the NGSS as its focus because of its contemporary nature in shaping the aims of science education within the United States. While Canadian educational policies or standards could have been selected to examine science education within Canada, the NGSS was chosen because of its position as a globally influential document. Due to the effects of globalization, interdependent and competitive relationships among nations ensure the far-reaching impact of the American educational standards, particularly to the Canadian education system.

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The Next Generation Science Standards was developed through partnerships between national educational organizations and corporate sponsors. The 1996 *National Science Education Standards (NSES)* was the precursor to this document. While only meant to be an advisory document, it exerted a strong influence on curriculum, pedagogy and assessment across states. This is similarly expected for the NGSS whose implementation at the state level has been highly encouraged. While only 14 states and the District of Columbia have formally adopted the NGSS, those states represent a significant fraction of the US population (Heitin, 2015).

**Research Questions**

This study analyzed the Next Generation Science Standards document through the theoretical framework of Actor Network Theory (ANT) while employing the methodology of critical discourse analysis (CDA). ANT is a theory and method of analysis that treats all aspects (both human and non-human) of the world as a product of networks and assumes that nothing has a form outside of these networks. It seeks to explore the development, stability and transformation of these networks and their heterogeneous elements (Law, 2009). Through ANT, this study has explored the networks that have contributed to the creation of the NGSS document, in addition to examining its influence on intersecting networks. CDA is a tool employed to deconstruct the ideologies and identify the existence of power structures present in discourse (Henry & Tator, 2000, p.18). Thus, CDA recognizes that discourse is not neutral, but rather it contributes to the reproduction of the unequal power dynamics between groups. Fairclough (2003, p. 8) states that texts influence knowledge, beliefs, attitudes, values,
and identities. In addition, he states that social life and practices are shaped by discourse and these social practices also serve to inform discourse (Fairclough, 2003, p. 2). While there are several ways in which CDA is taken up, this study has employed Fairclough’s approach to CDA to examine and deconstruct the discourses within the NGSS document.

In an effort to understand the discourses shaping science education, the study investigated the following research questions within the Next Generation Science Standards:

1. In what ways does the NGSS shape the discourse of science literacy and science education as a whole within the nation and elsewhere?

2. How does NGSS promote a democratic education (i.e. how does it address equity?)
   a. What is omitted in the STEM vision? If science is important for all students, what happens to those students that do not continue with science? How does it influence who has a voice in public and whose problems or interests are heard?
   b. How does it influence who we are educating? Or who is worth educating? (i.e. who is the ideal learner?)
Chapter 2
Literature Review

This chapter provides a review of the literature that has informed this study. The context of this literature review primarily focuses on US-based research as it aims to situate the Next Generation Science Standards. This chapter provides the historical and social context of science education and recent education reforms in the United States. It is important to understand that given the increasingly globalized world (as discussed later in this chapter), the reforms in the United States have far reaching implications for international education systems.

Scientific Literacy

Science/scientific literacy is an internationally identifiable phrase that has become synonymous with the goals of science education. It refers to what students are expected to know and be able to do at the end of their science education. While scientific literacy is deemed an essential outcome of science education, there is significant ambiguity surrounding the term. It has evaded a concrete definition over the years. The ambiguous nature of the term has allowed it to be variedly defined by the changing educational landscape.

Paul Hurd (1958) coined the term ‘scientific literacy’ in the late 1950s. However, discussions regarding the public having knowledge of science goes back to the beginning of the century (Shamos, 1995). As the emphasis of this study is on situating current
conceptions of scientific literacy within a historical context, the focus is on definitions of scientific literacy since the late 1950s.

The need for scientific literacy during the late 1950s was spurred by the launch of the Russian satellite Sputnik in 1957. The strategic role that science education could take on at this time was evident, particularly in garnering public support for science initiatives in the midst of the space race. Thus, scientific literacy took on a civic responsibility theme (DeBoer, 2000). In addition, Americans were concerned whether students were receiving the appropriate science education that would allow the US to remain globally competitive in the fields of science and technology (Hurd, 1958; Laukgsch, 1999). Increasing scientific literacy encouraged both the preparation of future scientists and a general public that would support scientific endeavours. This led to the development of science education programs that focused on disciplinary knowledge (knowledge relevant to the disciplines of science, such as biology, chemistry and physics).

In the 1970s, science literacy was criticized for its emphasis on disciplinary knowledge divorced from science’s everyday contexts and applications. Science reform then became more concerned with its social context in the 1970s and early 1980s (DeBoer, 2000). It was at this time that the National Science Teacher’s Association (NSTA) released a position statement on science-technology-society (STS) education, which led to the emergence of a STS-oriented curriculum (NSTA, 1982). The STS curriculum aspired to equip students with knowledge about the interrelationship between society and science and to foster development of skills necessary to make decisions about science-related social issues (Ramsey, 1989).
However, STS education was controversial as it prioritized social issues over disciplinary content (DeBoer, 2000). As this was debated, the National Commission on Excellence in Education (1983) issued its report, *A Nation at Risk: The Imperative for Educational Reform*. The report stated that the academic standards of the US had fallen as evidenced by the low test scores of American students in math and science. The release of this document led to a perceived crisis within the US education system. As a result, there was a push for “clear national performance goals”, as articulated by President Bush in 1989, which would make the US economically competitive (US Department of Education, 1991). This was motivated by the notion that the US was falling behind in economic competitiveness because students were not being adequately prepared for a world dominated by science and technology.

This ‘crisis’ led to the American Association for the Advancement of Science’s (AAAS) Project 2061 initiative. It published *Science for All Americans (SFAA)*, which defined a scientific literacy as being for *all* high school graduates (Rutherford & Ahlgren, 1989). The document, which called for a standards-based reform, defined a scientifically literate person as “one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes” (AAAS, 1989). *SFAA* (AAAS, 1989) outlined the knowledge, skills and attitudes that students should acquire in order to be scientifically literate. This was the first major reform initiative to encourage the inclusion of all
students in becoming scientifically literate (DeBoer, 1991). AAAS (1993) then published the *Benchmarks for Scientific Literacy* that provided curriculum design tools to implement a ‘science for all’ curriculum. Consequently, the National Research Council (NRC) developed *National Science Education Standards (NSES)* that corresponded with the vision of *SFAA* (NRC, 1996). Although education is under state control, *NSES* was a highly influential document in developing state standards until the recent introduction of the Next Generation Science Standards (Laukgsch, 1999; Roberts, 2007).

In addressing the numerous conceptions of scientific literacy over time, Roberts (2007) has organized them into two overarching visions of scientific literacy - Vision I and Vision II. While not all conceptions of scientific literacy within these categories are homogenous, they share a commonality that allows for this categorization.

Vision I denotes that the central aim of science education ought to be the promotion of scientific concepts and processes, which leads to a focus on disciplinary knowledge that is decontextualized from the sociopolitical. As Zeidler (2009) notes, this vision is encompassed by documents that identify scientific literacy as mastery of scientific concepts, such as *Science for All Americans* (AAAS, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993), which have informed the *National Science Education Standards* (1996). In contrast, Vision II conceives of understandings and uses of science within social contexts, thus emphasizing opportunities for students to use scientific ideas and processes as opposed to prescribing what individuals should know and be able to do. Most notably, STS falls within this purview of scientific literacy, as does other related efforts such as humanistic science education (Aikenhead, 2006),
citizen science (Jenkins, 1999), and socio-scientific issues (SSI; Sadler, 2004). These contrasting visions of scientific literacy are reflective of the often competing notions regarding the aims of science education amongst scholars and government organizations.

Globalization of Education

Carter (2005) defines globalization as a “complex dialectic of both political-economic and sociocultural transformations, which is as likely to enhance the local as much as it is the universal or global” (p. 562). Globalization is a combination of universalized homogenization through economic reforms and the diffusion of Western culture (Jameson, 1998). Thus, education needs to be re-examined through the lens of globalization.

Globalization has led to an interdependent and competitive relationship in economic productivity and educational achievement among nations. This is has stimulated the trend of an increasingly standards-based education system motivated by international comparisons of students’ performance on assessments (DeBoer, 2011). The underlying basis for such competitiveness is the belief that economic success of a nation is related to educational achievement, particularly in science and technological fields. There is also the belief that more prescribed learning goals and accountability through assessment will lead to improved learning (Carter, 2005). It is important to note that globalization can also benefit advancement in scientific knowledge needed to address global challenges.

Perhaps one of the most influential international organizing bodies of this standards based movement is the Organization for Economic Cooperation and
Development (OECD). OECD is the organizing body that is involved in providing international comparisons of student success in science education through PISA (Programme for International Student Achievement) assessment results. PISA is based on a competency model, in which an individual’s ability to apply scientific knowledge to real-life world problems is assessed, premised on OECD’s own conception of scientific literacy (OECD, 2007). PISA defines scientific literacy as (OECD, 2007, p. 23):

- “Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
- Understanding of the characteristic features of science as a form of human knowledge and enquiry
- Awareness of how science and technology shape our material, intellectual, and cultural environments
- Willingness to engage in science-related issues and with the ideas of science, as a reflective citizen”

PISA assessments are taken every three years in reading, math and science at the age of 15, which is near the end of mandatory educational enrollment in most countries (OECD, 2007). Another international assessment is the Trends in International Mathematics and Science Study (TIMSS) developed by the International Association for Evaluation of Educational Achievement. It is an assessment of math and science delivered every four years for students in grades four and eight (DeBoer, 2011). While PISA is a competency model based on an integrated approach to science knowledge, TIMSS assessments tend to be fact-based (Fensham, 1997).

The results of PISA are increasingly influencing countries’ conception of improvements in science education as improvements in international test scores. In response to PISA, other countries such as Denmark, Germany, and Portugal have
developed competency models of science education (Dolin, 2007; Langlet, 2007; Perrenoud, 1997). These international tests have resulted in countries, including the US, developing more specified learning outcomes to improve test scores (DeBoer, 2011). In fact, poor performance on PISA assessments as part of the rationale for the development of the Next Generation Science Standards (NGSS Lead States, 2013). Thus, international assessment results seem to be driving national education reforms as nations compete to stay ahead in the global race (DeBoer, 2011).

**Education Reforms & Standardization**

In order to better understand the current educational climate, this section explores major US education reforms from the past 20 years.

The No Child Left Behind (NCLB) Act was passed in 2001 under George W. Bush’s presidency and marked the largest intervention of education policy by the federal government in US history (Hursh, 2007). It aimed to improve education for all, particularly those who were historically disadvantaged (students of lower socioeconomic status and racial and ethnic minorities). It pledged “to close the achievement gap with accountability, flexibility, and choice, so that no child is left behind” (US Department of Education, 2003). It operated based on increased accountability measures through increased alignment with standards that were measured by state and national assessments. NCLB required students to be assessed every year from Grade 3 to Grade 8 and once in high school by standardized tests that aligned with national academic standards for reading, mathematics, and science. These assessments were developed and administered by the National Assessment of Educational Progress (NAEP) to compare
scores across states (US Department of Education, 2003). It penalized schools that did not make “adequate yearly progress” on each year’s tests. Each year of poor test scores would incur harsher sanctions, and after six years of failure, schools could be closed down or taken over (Darling-Hammond, 2013).

While the rhetoric of NCLB was democratic and inclusive, the realities have been damaging to the US education system. Several studies have shown that the increased accountability measures of NCLB had detrimental effects on poor and racial and ethnic minority students. These students experienced lowered expectations and their curriculum narrowed to focus on test preparation and basic skills, thereby limiting their engagement with science (Valenzuela, 2005; Lipman, 2004; McNeil & Valenzuela, 2001).

In addition, NCLB did not significantly contribute to closing the gap for poor and minority students (Lee & Orfield, 2006). In fact, in some cases, it increased inequality. The percentage of students graduating from high school decreased, particularly for students of lower socioeconomic status and racial and ethnic minorities (Darling-Hammond, 2013). In urban schools, students were either held back or forced out of school in order to increase the percentage of students passing the standardized exams (Darling-Hammond, 2013; Hursh, 2007; Meier & Wood, 2004).

NCLB expired in 2007 and despite its reputation of failure, the legislation (Elementary and Secondary Education Act) on which NCLB was based on still remains in place. In July 2015, the Senate passed a bill that would preserve this Act’s important tenets such as the use of tests as a measure of students’ academic progress but would
restore responsibility back to states, school districts and teachers for responding to the test results (Steinhauer, 2015).

Race to the Top (RTTT), the first education initiative introduced by President Barack Obama in 2009, effectively replaced NCLB, thereby trading one standards-based reform for another. RTTT is a $4.35 billion competitive voluntary grant program offered to the states (Onosko, 2011). States can win grants for satisfying certain educational policies, such as performance-based evaluations for teachers and principals, adopting common core standards, adopting policies that expand charter schools, and turning around lowest performing schools (Onosko, 2011).

The Common Core State Standards (CCCS), referred to by RTTT, was released in 2010 in response to the growing concern that students were not being adequately prepared for college and careers. The rationale for CCCS was to ensure that students across all states are held to the same common core standards that will prepare them for success. The US Department of Education awarded two assessment groups $360 million to develop national assessments aligned with the common core standards (Onosko, 2011). There was doubt that some states’ standards expectations were below what was necessary to succeed in college and careers. This was supported by comparative national scores from the National Assessment of Educational Progress (NAEP) that showed wide differences across achievements in mathematics and language arts. Despite the public criticism regarding the Common Core, it has been adopted by 43 states, mostly due to RTTT, which awards points to states based on adoption of these standards (Onosko, 2011).
While education is usually under the purview of state and local districts, the standards-based movement of the last 20 years has led to large-scale federal interventions such as No Child Left Behind and Race to the Top.

**Effectiveness of Standardized Testing**

In concert with National Defense Education Act’s (NDEA) initiatives at the time of the “Space Race” was the increased trend of employing standardized tests to measure competency. The NDEA (1958, p. 1592) called for,

“…A program for testing aptitudes and ability of students in public secondary schools, and…to identify students with outstanding aptitudes and abilities…to provide such information about the aptitudes and abilities of secondary school students as may be needed by secondary school guidance personnel in carrying out their duties; and to provide information to other educational institutions relative to the educational potential of students seeking admissions to such institutions…”

As a result, the NDEA provided states with funding to increase testing and guidance, with an emphasis on finding students with “outstanding aptitudes and abilities” (Resnick, 1982). This promoted an outcomes-based education, in which student competency was to be measured through outcomes in assessment.

Despite reform efforts and policies that support a standards-based regime dependent on high-stakes testing, there is considerable evidence to suggest that standardized tests are not without their problems.

Standardized tests can be problematic, as they have been found in some cases to be unreliable and invalid means of assessing student learning. In addition they may not
be well-suited in assessing students’ understanding of concepts (Sacks, 1999). This form of testing underrepresents students’ abilities, as there has been a lack of correlation between science curriculum and actual test items (Settlage & Meadows, 2002). Lewis, Baker & Jepson (2000) provide evidence of a steady decline in the perceived effectiveness of higher standards as a reform strategy.

Standardized testing limits the scope of what is being tested because it tends to leave out material that is generally associated with higher levels of application of knowledge and skills. (Hout & Elliott, 2011). Most states, particularly after the implementation of No Child Left Behind, use multiple choice-based tests to comply with requirements of annual testing. This narrows the scope of curriculum as teachers are forced to teach to the test format, even if it contradicts with their teaching philosophies (Darling-Hammond, 2003).

Standardized tests do not value student diversity as the tests are “normalized” for a particular section of the student population, which then may have unintended consequences for student learning (Kohn, 2000). This is particularly true for students of lower socioeconomic status and racial and ethnic minorities who tend to underperform on standardized tests in comparison to white students (Settlage & Meadows, 2002).

Scores on standardized tests are attached to rewards and sanctions, such as grade retention or promotion, graduation, merit pay, threats of dismissal for teacher and administration, and labelling of schools as failing which can led to school closures (Darling-Hammond, 2013). As a result of these pressures on schools and administration to perform on test scores, some schools have enacted “strategies” that improve their test
scores. This includes keeping low-achieving students out of testing, counselling students out of courses, transferring them to alternative classrooms and refusing to enroll low-scoring students (Lee & Orfield, 2006). A comprehensive nine-year study of testing and evaluation commissioned by the National Academy of Sciences has shown that test-based incentives do not improve education (Hout & Elliott, 2011).

**Tracking**

Standardized tests are also one of the primary means of tracking students into different academic streams based on their perceived abilities (Darling-Hammond, 2013). In the US, tracking (or streaming) begins in elementary schools on the basis of students’ test scores. However, studies have shown that tracking at such an early age leads to educational inequalities (OECD, 2007). There is a disproportionate number of minority students and students of lower socioeconomic status placed in low-ability or non-college bound tracks. These students are also underrepresented in gifted tracks. This contributes to the racial segregation of schools (Oakes, 2005; Rosenbaum, 1980).

Low-level track classes have been found to focus on behavioural skills and a rote-learning curriculum that discourages critical thinking and in one case, resulted in the complete absence of any teaching of the subject matter (Anyon, 1980; Oakes, 2005; Page, 1989, 1990). This seems to explain the disparity in achievement, graduation rates, and college pursuits of students in lower tracks. Tobin, Seiler, and Walls (1999) argue that these schooling practices result in an institutionalization of low expectations for these students and as a result, students engage in forms of resistance that reinforce the stereotypes of minority and high-poverty students as academically inferior. Thus, there is
a hidden curriculum in schools based on the perceived competencies of students, which is informed by the social class hierarchy. As a result, the hidden curriculum ultimately reproduces the existing class structure (Anyon, 1980).

Mickelson & Everett (2008) reveal a new form of tracking as operationalized in North Carolina - “neotracking” - which creates a multi-layered tracking system that further stratifies educational opportunities by race and class. Neotracking combines within-subject area curricular differentiation (Regular, Advanced, Honours, Advanced Placement, and International Baccalaureate Program) with college and career tracks (Career Prep, College Tech Prep, College/University Prep). North Carolina created college and career tracks as a result of pressure to improve the school-to-work transition. Neotracking, reproduces inequalities, as racial and ethnic minorities are less likely to be found in the college/university prep courses in North Carolina. This form of neotracking has historical roots as past US reform movements within schools and universities also evolved to meet the needs of the labour force (Bowles & Gintis, 1976).

Despite evidence that tracking is ineffective, particularly for students in lower tracks, it is entrenched in the schooling system (Oakes, 1987). The schooling context shows clear advantage for students in the top tracks, in terms of instructional quality, available resources, access to knowledge, and academic expectations. The societal context highlights that the tracking system in a given school is based on perceived differences of student needs, governed by race and social class hierarchy, which ultimately results in differential educational implications. Tracking embodies deep-seated beliefs about abilities, cultural deficits and the strengths and deficits of various groups
Detracking has been shown to be successful in closing the gap, but it requires adequate teaching and support resources (Boaler & Staples, 2008). The schooling and societal contexts of tracking are built upon the basis that tracking best serves the education of a diverse student body. Thus, a consideration of an alternative to tracking would entail questioning the fundamental aspects of schooling practices (Oakes, 1987).

**School-to-prison Pipeline**

High-stakes testing is a culprit in the school-to-prison pipeline in which low-income and minority students are the victims. It has resulted in lowered rates of achievement, graduation, and college enrollment (Wald & Losen, 2003). High school dropouts compose 82% of the adult prison population and 85% of juvenile justice cases (Christle, Jolivette & Nelson, 2005). This trend is associated with school practices that are increasingly punitive (Wald & Losen, 2003). Thus school factors may play a greater role in youth delinquency than student characteristics (Wu, 1980). The harsh sanctions associated with failure of standardized testing has resulted in more students being held back or pushed out. Minorities tend to be overrepresented in schools that are harshly sanctioned. There are higher rates of retention and dropping out for these vulnerable groups when there are test-based promotion and graduation requirements (Darling-Hammond, 2013). Academic failure, suspension and dropout rates contribute to increased youth delinquency (Christle, Jolivette & Nelson, 2005). Thus, the practice of high-stakes testing and its punitive measures has played a role in contributing to the flow of students from school to prison.
Alternatives to STEM Education

The first chapter of this thesis explores the place of the Next Generation Science Standards within the STEM movement. It would be remiss to not discuss the other approaches to science education that strive for democratic engagement within science education.

One of the earliest approaches that countered the movement of curriculum towards decontextualized disciplinary knowledge was the science, technology and society (STS) approach (DeBoer, 2000). STS education privileged the understanding of the relationship of science and technology with society. Over the years, the STS approach has evolved to become STSE education, the “E” representing environment.

STSE at its basic level is the interaction of science with the social world. It has evolved out of social and political issues that have resulted in an increased attention to science and civic responsibility. For many, STSE is a more inclusive approach to science education that articulates a “science for all” philosophy. However, STSE is understood and enacted in diverse ways, influenced by various ideologies & pedagogies, thus defying a unified definition. Pedretti & Nazir (2011) have mapped out the STSE field by identifying six currents: application/design, historical, logical reasoning, value-centered, sociocultural, and socio-ecojustice currents. Although these currents differ in their underpinnings, they all emphasize key tenets of STSE, which fosters a scientific literacy that encompasses informed decision making through critical analysis of scientific knowledge, nature of science (NOS) perspectives, moral reasoning, and agency.
Another approach that runs parallel to STSE is the socioscientific issues (SSI) approach to science education as established by Zeidler, Sadler, Simmons and Howes (Zeidler et al., 2005). While similar in vein to STSE, SSI is described as a domain that “focuses on empowering students to consider how science-based issues reflect, in part, moral principles and elements of virtue that encompass their own lives, as well as the physical and social world around them” (Zeidler et al., 2015, p. 135). SSI differentiates itself from STSE with its emphasis on developing habits of minds (ie. skepticism, open-mindedness and accepting ambiguity) as part of the psychological and epistemological growth of students. In addition, while STSE examines the moral and ethical issues embedded in science-related issues, SSI addresses these issues in connection with the character development of students (Zeidler et al, 2015).

While Hodson (2010) acknowledges the broadening of the scope of science education in the SSI approach as compared to STSE education, he states that both approaches do not go far enough. He proposes a politicized form of SSI-oriented teaching and learning in which students address complex and controversial socioscientific issues (Hodson, 2010). His form of scientific literacy encourages students to critically examine society, comprehend the values that underlie it, and determine what needs to be changed in order for a just and democratic society. Thus, Hodson (2010) proposes a curriculum that encourages and prepares students to engage in sociopolitical action, such that they are not merely using and critiquing scientific knowledge, but they are themselves creating it through action.
Therefore, while the STEM movement is gaining traction in national discourse, there are several other approaches to science education that aim to engage students through meaningful and relevant learning experiences.

In order to develop a better understanding of the current educational landscape that frames this study, this chapter has provided a historical overview of the evolving nature of science education within the United States.
Chapter 3
Methodological Framework

This chapter describes the methodological framework of this study. It begins with an overview of Actor Network Theory (ANT) – the theoretical framework that has guided the research process. It is followed by a discussion about the qualitative approaches of grounded theory and critical discourse analysis (CDA) that were applied to analyze the Next Generation Science Standards.

**Actor Network Theory**

Actor Network Theory (ANT) emerged in the 1980s from science and technology studies (STS) as a conceptual framework used to explore the complex workings of sociotechnical processes (Ritzer, 2004). Its progenitors Michael Callon, Bruno Latour, and John Law contributed to an understanding of the world as a product of continuously generated networks of “actants” (human and non-human entities). Its initial studies examined science and technology in laboratories but have since extended to public and private sectors (de Laet & Mol, 2000; Law & Callon, 1992).

Key proponents of ANT do not acknowledge it as a theory, as it is more descriptive than explanatory in its forms. It is considered more of a sensibility – a way of examining the relationality and materiality of our world (Law, 2004). ANT is a “disparate family of material-semiotic tools, sensibilities and methods of analysis” that challenges some common central epistemological and ontological assumptions (Law, 2008, p. 141). ANT takes on a priori assumption of networks, in which entities (actants) -
both human and non-human - are not fixed and do not have an identity unto themselves. They only exist and achieve significance through the relations/networks that produce them (Law, 1992).

A key assumption identified by Latour (1987) is “symmetry” in which humans and non-humans are treated equally in ANT analyses. Thus, all entities (humans & non-humans) are “actors/actants” that have the ability to act (ie. have agency) and can be acted upon. This distinguishing feature of ANT separates it from other frameworks. In addition, ANT resists against such dichotomies of “social/society” and “nature” and argues against relations in these isolated domains. Instead, it proposes a “society-nature” hybrid that acknowledges the world as a product of networks composed of heterogeneous relations between humans and non-humans (Callon, 1986; Nimmo, 2011).

Actor-networks are dynamic systems of relations composed of actants/actors who become defined and constituted (take on meaning) through these associations. The objective of ANT is to explore the development, stability and transformation of these networks and their heterogeneous elements (Law, 2008). ANT lets go of assumptions of scale. A network is never bigger or smaller than another, it is merely longer or more intensely connected. These networks are dynamic and are continually reconstructed (Ritzer, 2004).

Networks can gain stability or dissolve. ANT allows analysis into examining how some connections are supported to make networks stable and durable. ANT analyses focus on the negotiations that occur at points of connections that allow networks to exert
power and other effects (Fenwick, 2010). The focus of ANT is not to explain why things are but to explain how they came to be and how they are enacted (Fenwick, 2010).

**Translation**

In order to examine how some networks become stable and durable over time, it is important to uncover the underlying power relations. According to ANT, power is *produced* through networks of socio-material relations. Thus, it is a productive model of power, in which actants do not possess power, rather, power is derived from the actions of other actants, who can then translate it or shape it to their needs. Therefore, power is a result of translation as opposed to possession.

Translation is the means by which a network progressively takes form. It involves a group of actants that coordinate themselves to a common cause, resulting in certain actants controlling others. Callon (1986) identified four “moments” in translation: problematization, interessement, enrollment, and mobilization. Translation begins with problematization where primary actants define and frame the nature of the problem. Interessement involves different actants recognizing the need to align themselves to this framing (a common cause), while other actants are excluded. If this succeeds, the actants are enrolled in the network, in which their interests are negotiated with other actants toward the common cause. When an actant becomes translated, it appears to behave with intentions and morals of the network (Fenwick, 2010). Mobilization involves some of the actants becoming spokespeople or representatives in order to recruit more allies to the network. Therefore, the network’s stability lies in the continual translation of interests.
(ie. power) among actants (Callon, 1986). ANT analyses help to examine how certain networks can solidify relations of power (Fenwick, 2010).

Translation is unpredictable, as there is no way to determine how entities will act when they come together. They are constantly negotiating their connections through persuasion, force, logic, resistance, and accommodation. Some connections may be more durable than others and translations may proceed gradually or be delayed through space and time (Fenwick, 2010). Some entities may only be partially translated by the network. Entities undergo numerous negotiations in the process of translation (Latour, 1987). Entities are not only effects of relations but also actively act on others and have agency. All negotiations or connections are fragile and become strong by assembling more allies into the network (Fenwick, 2010). If the process of translation settles and the network becomes a stable process, the network may become a “black box” through punctualization (Latour, 1987). Punctualization refers to the process in which an entire network is disguised so that it is seen as a single actant (Callon, 1991). However, an entity can be de-punctualized through competing ideas that seek to open the black box (Callon & Latour, 1981).

ANT was chosen as the theoretical framework of this study because of its foundational principle that the world and the components that construct it are a collection of dynamic networks. Any entity, whether it is an individual, organization, inanimate object, or even a theoretical concept is a result of a network. For example, a classroom is a network composed of actants that include students, teachers, desks, chairs, paper, curriculum, assessment, and standards. Each of those actants are also composed of their
own networks. It is the interplay between these actants through which actants derive their nature and can exert effects, such as power. Thus, entities such as curriculum, standards, reforms, policies, assessment, inequities are themselves composed of complex interrelated networks that assemble to govern educational practices (Fenwick, 2010).

This is particularly pertinent for this study because a document such as the NGSS is not constructed and delivered in isolation. It is the result of historical movements within science education in the US. It is informed by competing and parallel perspectives about the aims of science education. Moreover, the document itself was developed as a collaboration between multiple national organizations and corporations, with input from scientists, researchers, and policy experts. The NGSS is a byproduct of the voices of these multiple networks and it is important to identify and examine their influence within the document.

**Methodology**

The following section outlines two methodological approaches, grounded theory and critical discourse analysis, which were used to conduct the analysis of this study. Methods from these approaches allowed exploration of the discourses of science education and the power relationships that govern them.

**Grounded Theory**

Barney Glaser and Anselm Strauss (1967) developed grounded theory as an inductive approach that allowed theory to emerge through qualitative analysis of data. It
challenged the methodological restrictiveness of the deductive approach at the time, in which developed theories were applied to collected data. Grounded theory involves multiple stages of gathering, integrating and categorizing data (Strauss & Corbin, 1990).

Since then, Glaser and Strauss have diverged in their understandings of grounded theory. Glaser’s perspective is very open and is predicated on having no preconceived ideas before entering the research process. He viewed all background knowledge as detrimental (Glaser, 1992). Therefore, Glaser (1992) preferred to enter the research process without having read pertinent literature or having research questions in mind. In addition, he encouraged an ongoing open coding process, in which codes are subject to change as “coding families” or themes emerge (Glaser, 1992).

In contrast, Strauss and Corbin (1990) stressed the importance of having open questions in mind when entering the research process. In that vein, they recommend reading relevant literature prior to conducting any research in order to help formulate questions. In addition, they advocated for a multi-stage approach to coding where initial codes are summarized based on how they fit into categories (Strauss & Corbin, 1990).

This study embraces both approaches to grounded theory. In accordance with Strauss & Corbin’s (1990) approach, relevant literature was read and the coding process was approached with open research questions in mind (as outlined in Chapter 1). However, the process of coding was open and ongoing, as advocated by Glaser (1992), which allowed for themes to emerge. The constant comparative analysis (CCA) method used to construct the overarching themes is discussed later in the data analysis section.
Critical Discourse Analysis

Critical Discourse Analysis (CDA) explores the relationships between discursive practices, events, and texts within the broader social, cultural and historical contexts (Fairclough, 2001).

In order to appreciate critical discourse analysis as a theory and method, the importance of language must be considered, not only for how we communicate with others but also for the role it plays in how we construct our realities. Language is what we use to create representations of reality, which are not necessarily reflections of a pre-existing reality (what is ‘out there’), but are products of language and discourse (Jorgensen & Phillips, 2002). Language frames the world and in doing so, constructs social identities and social relations (Jorgensen & Phillips, 2002).

Given that language is key to constructing our social reality, including social relationships and social identities, CDA explores how this is accomplished through language in texts. Several forms of CDA have emerged that employ different strategies for conducting discourse analysis. While this study employs Fairclough’s approach to CDA, the different approaches share central tenets that guide them, which are outlined by Fairclough & Wodak (1997, p. 271-280) below:

- “CDA addresses social problems
- Power relations are discursive
- Discourse constitutes society and culture
- Discourse does ideological work
- Discourse is historical
- The link between text and society is mediated
- Discourse analysis is interpretative and explanatory
- Discourse is a form of social action.”
Discourse is not merely language but involves “semiosis” (meaning-making) and the tools used to arrive at meanings. There are other semiotic forms such as images, sounds, and body language. However, Fairclough focuses on language because he considers it to be the most important semiotic form (Fairclough, 2001). Therefore, Fairclough takes up a textually-oriented approach to discourse analysis. He views discourse as dialectical - language is a social practice that both informs and is informed by social reality (Fairclough, 2003).

CDA also recognizes that discursive practices are ideological. Fairclough defines ideology as “a system of ideas, values, and beliefs oriented to explaining a given political order, legitimizing existing hierarchies and power relations and preserving group identities” (Chiapello & Fairclough, 2002, p. 187). Thus, ideologies work to reproduce unequal relations of power. Texts are one of the vehicles of that disseminate ideologies, which is an important point of analysis in CDA. CDA not only describes discourse practices, but attempts to expose oppressive discourses by uncovering underlying ideologies (which include taken-for-granted values and assumptions) within a text (Fairclough, 2003). Therefore, Fairclough considers CDA as not only a form of analysis but also a tool that can bring about transformation. Exposing the oppressive forces of power can serve as a form of “consciousness raising” or conscientization, as utilized by Paulo Freire (1970). CDA is a method that can disrupt these oppressive forces by exposing them and creating spaces to take action. In doing so, there is the possibility for transformation (Fairclough, 2001).
Fairclough’s method of CDA was used to conduct further analysis of the themes or discourses that emerged from using grounded theory. The specific methods are described in the data analysis section.

**Data Source**

The Next Generation Science Standards is over 250 pages which includes the standards, as well as supplementary sections and appendices. The NGSS was developed based on the *Framework for K-12 Science Education* (NRC, 2012), which is referenced frequently throughout the document. The NGSS contains the guidelines for the K-12 standards of science education. The standards are separated into three broad grade bands: elementary (Kindergarten to Grade 5), middle school (Grade 6-8), and high school (Grade 9-12). For the elementary level, the standards are assigned to specific grades. However, the standards are combined without any grade distinctions for the middle school and high school grade bands.

The entirety of the NGSS document was not examined for the purpose of this thesis. The analysis of the standards only extended to the high school grade band. The high school band was chosen because the interest of this study aimed to analyze the knowledge and skills included in the standards as necessary for students’ preparation for college and careers. However, the rest of document, including all the appendices, was examined. There are 13 appendices in the NGSS document that provide further rationale regarding the structure and development of the standards. This includes such appendices as, Appendix C: College and Career Readiness, Appendix D: All Standards, All Students/Case Studies, Appendix F: Science and Engineering Practices, Appendix H:

**Structure of the Next Generation Science Standards**

Within the grade bands, the standards are further divided into three disciplines: Physical Science, Biological Science, and Earth and Space Sciences. The Physical Science discipline contains the standard guidelines for the traditional school subjects of chemistry and physics.

Each topic in the NGSS is broken down into a set of performance expectations. They are the “assessable statements” of what students are expected to know and be able to do at the end of each grade band (NGSS, 2013b).

Some states take the performance expectations alone to be the “standards” (NGSS, 2013b, p.2). However, a more coherent view of what students are expected to do, according to the NGSS, comes from viewing the performance expectations in tandem with the content of the foundation boxes found below the performance expectations, as illustrated in Figure 1. These three boxes include the practices, core disciplinary ideas, and crosscutting concepts, derived from the Framework, that were used to construct the set of performance expectations. The practices refer to the “Science and Engineering Practices” that the NGSS have included in an effort to incorporate the practices of scientists and engineers as a way to develop inquiry skills. The “Disciplinary Core Ideas”, taken directly from the Framework, outline the science content knowledge that relates to the expectations. Finally, the “Crosscutting Concepts” are ideas that have applications across all domains of science. They consist of three categories: Nature of
Science (NOS), the Interdependence of Science and Engineering, and the Influence of Engineering, Technology, and Science on Society and the Natural World. The concepts are expected to be taught and assessed in the context of specific science ideas (NGSS, 2013b, p.5).

The standards will be referenced throughout the study in an abbreviated manner as written in the NGSS. For example, HS-LS2-7 refers to a standard in the High School (HS) band under the Life Science (LS) discipline. Similarly, PS and EES refer to Physical Science and Earth and Space Sciences respectively. An example of a standard in the NGSS is found in the Appendix.

Figure 1. Organizational structure of standards in the NGSS.
Data Analysis

The methods of analysis conducted in this study are derived from grounded theory and critical discourse analysis. The initial themes or discourses in the NGSS emerged through constant comparative analysis (CCA). These discourses were subsequently further explored through critical discourse analysis to uncover the underlying ideologies, values and assumptions found within the text.

Constant Comparative Analysis

The Constant Comparative Analysis (CCA) method, which follows from grounded theory, is an inductive process of reducing data through constant recoding (Glaser & Strauss, 1967). The constant comparative method develops themes from the data by coding and analyzing at the same time. In the process of coding, incidents or data (ie. codes) are compared to other incidents. Constant comparative analysis incorporates four stages: “(1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) delimiting the theory, and (4) writing the theory” (Glaser & Strauss, 1967, p. 105). This process begins with open coding to develop ongoing “coding families” or categories, followed by further reducing and recoding which allow core categories to emerge (Glaser & Strauss, 1967). This method of data analysis is used to construct themes that reflect that recurring patterns found in the data.

Initial analysis of the NGSS was conducted through the constant comparative method. The NGSS was first read without conducting any analysis in order to understand the structure of the document. In the second reading, open coding guided by the research
questions was employed. Ongoing coding revealed “coding families” or themes. In the third and fourth reading of the document, the codes were further reduced and recoded into several core themes or discourses. The document was read a final time to ensure thematic saturation. The analysis of the data was cyclical, consisting of initial coding, reflecting, re-reading, then sorting through the codes to discover patterns and themes.

**Critical Discourse Analysis Methods**

Following the constant comparative analysis, the core themes or discourses were subject to critical discourse analysis to examine the ideological underpinnings of the text. Fairclough (2003) developed a three-dimensional framework of analysis to study the relationship between discourse and the wider sociocultural contexts, as illustrated in Figure 2. There are three levels of analysis: text (language of the text), discursive practice (production and consumption of the text) and sociocultural practice (the broader social contexts in which the analysis of the document takes place).

![Fairclough’s three-dimensional framework of critical discourse analysis (CDA)](image-url)
The first dimension, discourse as text, is the study of the textual features of discourse. This can include word choice, grammar and the use of textual processes, such as the use of metaphors and nominalization. The first dimension explores how the choices of textual features are used to convey values, assumptions and ideologies. Fairclough’s textual analysis considers four categories: vocabulary, grammar, cohesion and text structure. Though there are several techniques of linguistic analysis identified by Fairclough (2001, 2003) within these categories, those used in this study are outlined in Table 1. While a rigid quantitative analysis was not undertaken, frequencies of certain word choices or themes were recorded.

The second dimension, discourse as discursive practice, examines the process of the text’s production, distribution and consumption. It specifically focuses on the concept of intertextuality, which is “the property texts have of being full of snatches of other texts, which may be explicitly demarcated or merged in, and which the text may assimilate, contradict, ironically echo, and so forth” (Fairclough, 1992, p. 84). The intertextuality of the NGSS was made clear within the document as it stated its influence from the National Science Education Standards (NRC, 1996) and Benchmarks of Scientific Literacy (AAAS, 1993). This was explored by comparing a selection of content across all three documents. In addition, intertextuality was explored by situating the NGSS document within its historical context and also by examining the process of its development.

The third dimension, discourse as social practice, concerns the text’s relation to its context (social, political, and historical), and the social identities and relations that it
affects within that context. The third level of analysis was conducted by examining the influence of the NGSS and its effects on national and international education systems. This is fully explored in the final chapter of this study.

Table 1. Fairclough’s techniques of textual analysis

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Word Choice</strong></td>
<td>Are words drawn from different classification schemes? Are there distinctions between formal and informal word usage? Are there instances of rewording or overwording? What metaphors are used? (Fairclough, 2001, p. 92-97)</td>
</tr>
</tbody>
</table>
| **Speech function** | Consists of demand, offer, question or statement. Statements are further categorized into:  
  **Realis:** A statement of fact – what is, was, or has been the case (Fairclough, 2003, p.109).  
  **Irrealis:** Hypothetical or predictive statements (Fairclough, 2003, p.109).  
  **Evaluation:** Statements that reveal value judgements (both implicit explicit) i.e. what is good or bad (Fairclough, 2003, p.215). |
| **Nominalization** | “A type of grammatical metaphor which represents processes as entities by transforming clauses (including verbs) into a type of noun…It is a resource for generalizing and abstracting which is indispensible in, for instance, science, but can also obfuscate agency and responsibility” (Fairclough, 2003, p.220) |
| **Legitimization** | “A widespread acknowledgement of the legitimacy of explanations and justifications for how things are and how things are done” (Fairclough, 2003, p.219) |
| **Rationalization** | “Legitimization by reference to the utility of institutionalized action” (Fairclough, 2003, p.98) |
| **Recontextualization** | Recontextualization is the relationship between different social practices. It examines how aspects of different social practices are reconstituted in others. (Fairclough, 2003, p. 222) |
Limitations

Consistent with the nature of research, there are limitations to this study. Both grounded theory and critical discourse analysis have various forms and therefore, different approaches to conducting data analysis. There is likely to be variations in findings across these different approaches and verification is unlikely.

This study aimed to examine how the NGSS shapes the discourses of science education within the United States. While a historical context was taken into account and other national documents were referenced, the findings of this study are limited as it only conducted detailed data analysis on one national document. The findings of this study can qualify some of the discourses present in science education but it cannot be generalized to be representative of the entirety of the discourses. However, it is important to note that the issue of generalization is less frequently discussed in qualitative research. Generalization is controversial because the main goal of qualitative research is to provide a contextualized understanding of the data.

Moreover, qualitative research is inherently embedded in subjectivity as authors are likely to influence the research process. It can be argued that any analysis is always partial and is biased by the researcher’s perceptions and understanding of the text (Fairclough, 2003). Thus, the role of this researcher as a science educator is embedded in the analytical process. However, in order to limit researcher bias, this researcher situated herself within the research by exploring predispositions and biases prior to data collection and analysis.
Chapter 4
Findings & Analysis

This chapter presents the findings of the study which center on discourses of science education and equity as illustrated in the Next Generation Science Standards. The chapter is organized into the major themes that emerged from data analysis methods as described in Chapter 3. Each section begins with findings from the NGSS, which are then organized into a coherent analysis of emergent themes at the end of each section.

1. Depth & Breadth of NGSS – An Authoritarian Rule

This section explores how the content and language of the NGSS creates an authoritative discourse in relation to the learning and practice of science education.

Content Distribution

While the main assessable components of the NGSS are the performance expectations, they are built on science content knowledge, which the NGSS identifies as disciplinary core ideas (DCI). One of the assertions of the NGSS is that it focuses on a smaller set of disciplinary core ideas in order to foster deeper understanding of content. It further states that the focus of instruction should be on the core performance expectations rather than the facts and details of the disciplinary core ideas (NGSS, 2013a). Prior to the NGSS, it was the National Science Education Standards (NSES) and Benchmarks for Scientific Literacy documents that guided state curriculum development and assessment.
Therefore, the content focus of *NSES* and *Benchmarks* were compared with NGSS in order to determine how significantly the new document has narrowed its focus.

The physical sciences standards between the NGSS document, *NSES*, and *Benchmarks* were compared based on amount of content. An example of this comparison is illustrated in Table 2, which compares one performance expectation in the NGSS, its associated DCI and the associated content found in *NSES* and *Benchmarks*. The table has been colour coded to illustrate similar concepts covered across the three documents. Although there are fewer DCIs that are written out in the NGSS, the amount of actual content that needs to be learned by the student has not been reduced in any significant manner. The DCIs in the NGSS are thematic and overarching statements about science concepts, while the *NSES* and *Benchmarks* deconstruct and unpack these concepts into their foundational facts. The NGSS states that the focus is on the core ideas rather than the facts, but the performance expectations tend to encompass these facts regardless.
Table 2. Physical Science Performance Expectations and Associated Content in the NGSS, NSES and Benchmarks.

<table>
<thead>
<tr>
<th>Performance Expectation (NGSS)</th>
<th>DCI (NGSS)</th>
<th>NSES</th>
<th>Benchmarks</th>
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<tbody>
<tr>
<td>HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]</td>
<td>• Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)</td>
<td>• Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge.</td>
<td>• Atoms are made of a positively charged nucleus surrounded by negatively charged electrons. The nucleus is a tiny fraction of the volume of an atom but makes up almost all of its mass. The nucleus is composed of protons and neutrons, which have roughly the same mass but differ in that protons are positively charged while neutrons have no electric charge.</td>
</tr>
<tr>
<td></td>
<td>• The periodic table orders elements horizontally by the number of protons in the atom’s nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2)</td>
<td>• Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.</td>
<td>• The number of protons in the nucleus determines what an atom’s electron configuration can be and so defines the element. An atom’s electron configuration, particularly the outermost electrons, determines how the atom can interact with other atoms. Atoms form bonds to other atoms by transferring or sharing electrons.</td>
</tr>
<tr>
<td></td>
<td>• Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.</td>
<td>• An element is composed of a single type of atom. When elements are listed in order according to the number of protons (called the atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This ”Periodic Table” is a consequence of the repeating pattern of outermost electrons and their permitted energies.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Each atom has a positively charged nucleus surrounded by negatively charged electrons.</td>
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</table>

The Focus on Content Knowledge

The NGSS states that performance expectations should focus on “understanding and application as opposed to memorization of facts devoid of context” (NGSS, 2013b, p. 1). The NGSS aspires for a contextualized understanding of science and thus, performance expectations that have real-world applications. The NGSS hopes to achieve
this by having each performance expectation incorporate a Science & Engineering Practice in order to develop knowledge understanding and application (NGSS, 2013a).

The presence of contextualized knowledge within the performance expectations of all three science disciplines was examined. Contextualized knowledge was identified on the basis of whether the performance expectations (and the subsequent clarification statements) indicated any real-world application of content.

For example, the Physical Science performance expectation within the topic of “Matter and its Interactions” states:

“Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.]”

While this performance expectation illustrates the use of developing models to show an understanding of the processes of fission, fusion, and radioactive decay, there is no reference to applications of this content knowledge, such as connections to nuclear energy. This is common throughout the NGSS, particularly in the Physical Science section in which language supporting the Science & Engineering Practices will be used such as, ‘develop models’, ‘use mathematical representation’, ‘plan and design an investigation’, ‘evaluate claims, and ‘construct explanations.’ However, some expectations associated with such terms still tend to be focused on content knowledge that lacks application.
In contrast is the Biological Science performance expectation within the topic of “Biological Evolution: Unity and Diversity”:

“Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.[Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]”

The application of this performance expectation is in its contextualization of biodiversity within the larger scope of society. In addition, it also directs the engineering of a solution to address this issue. Thus, this performance expectation provides a clear direction for application of knowledge.

This criteria was used to examine the presence of contextualized performance expectations in the three disciplines and the findings are presented in Table 3. The parentheses indicate the total number of performance expectations within each discipline.

As illustrated in the table, there is very little evidence of contextualized performance expectations in the disciplines. The instances of contextualized knowledge are less than 10% across all three disciplines. There appears to be a focus on theoretical knowledge without presenting opportunities for contextualization and application.
Table 3 Contextualized Performance Expectations found in the NGSS.

<table>
<thead>
<tr>
<th>Science Discipline</th>
<th>Contextualized Performance Expectations</th>
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<td>HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</td>
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<td>HS-LS2-7 Evaluate the evidence for the role of group behavior on individual and species’ chances to survive and reproduce.</td>
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**Language Clarity of Performance Expectations**

The language used to describe the performance expectations was examined to determine how the NGSS fared in delivering an accessible standards document, particularly as it notes that “performance expectations are the policy equivalent of what most states have used as their standards” (NGSS, 2013b, p.1). Therefore, these expectations carry weight in state and classroom implementation, thereby necessitating the need for clear directives.
Many of the performance expectations were couched in technical terms related to their associated discipline. For example, a performance expectation under the Life Science discipline states:

“Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy. [Clarification Statement: Emphasis is on the conceptual understanding of the inputs and outputs of the process of cellular respiration.] [Assessment Boundary: Assessment should not include identification of the steps or specific processes involved in cellular respiration.]”

In attempting to describe cellular respiration, this statement overly complicates the process of cellular respiration and emphasizes it on a molecular level. Interestingly, the clarification statement seeks to emphasize the conceptual understanding, but the language of the expectation itself fails to do so.

The following are examples from Physical Science and Earth and Space Science respectively:

“Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics) [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]”

Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass
wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth’s surface.]

In addition to the first expectation being technical, it is also convoluted and confusing to the reader. However, it does attempt to unpack the theoretical basis of the second law of thermodynamics. The clarification statement provides an example of using investigations, such as the mixing of liquids at different temperatures. This simplicity of the investigation (to show that when liquids of two different temperatures are mixed in closed environment, they will reach a common temperature) is in contrast with the language of the performance expectation.

The second expectation is also unclear due to the use of vague language, such as ‘internal, ‘surface’, ‘spatial’ and ‘temporal’. It is easily explained in the clarification statement, which would have been preferable to use as the performance expectation for the purpose of clarity.

The NGSS document emphasizes the importance of critical thinking and inquiry-based learning. However, the performance expectations that encourage such skills reflect a high level of prescription. For example, a Physical Science performance expectation within the topic of “Structure and Properties of Matter” states:

“Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.”

While this statement encourages the development of models (a Science & Engineering Practice), it dictates what the model should illustrate instead of encouraging a more open-
ended investigation, such as: “Develop a model to explore the factors that contribute the release or absorption of energy in a chemical reaction.”

This level of prescription is found throughout the NGSS. Another example can be found in Earth and Space Sciences:

“Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation.”

While the standards encourage the use of models and investigation, prescribing the conclusions that should be attained takes away from the investigative nature of science. Therefore, the task no longer functions as an investigation and fails to develop meaningful critical thinking and inquiry skills.

**Analysis – An Authoritarian Rule**

As the above analyses show, the NGSS contains prescribed knowledge that has a technocratic focus – one in which there is significant emphasis on technical knowledge associated with science disciplines with little room for contextualization and application.

Since the NGSS will guide state curriculum, this technocratic focus is likely to be reflected in classroom practices where students will be required to use technical knowledge. The use and understanding of technical knowledge is important to the shared meaning in science disciplines (Gee, 2004). However, in some cases, students will repeat technical knowledge without understanding or negotiating the need for that knowledge (Lemke, 1990). Thus, standards couched in this form of technocratic language may make it difficult for students to engage in authentic science learning experiences (Knain, 2005).
The prescription of language in the NGSS document reflects an authoritarian model of education in which the knowledge and how it must be “mastered” is dictated (Wallace, 2012). Highly specified standards have proved to be detrimental to children's interest in learning science because they lead to a rushed and content-dominated curriculum that doesn't allow for the time to develop critical thinking skills (Lyons, 2006). An encouragement of investigations through inquiry-based learning would detract from this. However, even these types of investigations tend to be prescribed in the NGSS, thereby defeating their purpose. Further, the NGSS largely presents decontextualized knowledge, which is contrast with research that shows children's learning processes are fostered through an inclusion of sociocultural context (Wallace, 2011).

Zeidler (2014) categorizes the practice of science has having non-normative (ie. data gathering, observation, predictions, models) and normative components (ie. prescribing courses of action, decisions about what ought to be done). He goes on to state that the STEM movement privileges non-normative components at the detriment of normative ones (Zeidler, 2014). This was also exemplified in the NGSS. Science and engineering practices (non-normative components) were encouraged while failing to address the sociocultural contexts of science in everyday decision making processes (normative components).

The highly specified nature of the NGSS is reflective of a “content-and-product” model (Kelly, 1999). This model assumes there is a body of high-status knowledge that must be learned and that this content is the most important aspect of education (Apple,
The product aspect illustrates how this content must be translated into educational outcomes. These outcomes tend to be behavioural objectives that are decontextualized disciplinary knowledge, as illustrated in the NGSS. In addition, the NGSS also specifies assessment boundaries that serve to limit the extent to which students need to be engaged with the topic. Teachers are expected to prove the achievement of these outcomes through standardized test scores, which forms an essential part of the accountability system in education (Wallace, 2012).

The NGSS is clear in indicating that the standards are not curriculum and that the flexibility of teaching practices is up to the teachers, which seems to promote democratic participation (NGSS, 2013a). However, the emphasis on a large body of content that is highly specified restricts the flexibility of teachers and reflects a non-participatory epistemology (Wallace, 2012). In addition, while curriculum developers place the emphasis of contextualization on teachers, the assessments are typically not contextualized (Ball, 2003). Therefore, this model of an authoritarian standards document deflects from meaningful educational experiences.

2. A reconceptualization of scientific literacy

This section outlines two interrelated discourses – science education for work and the constitution of technology within the NGSS. Each discourse is organized with findings from the NGSS followed by an analysis of factors contributing to the discourse. They have been organized under the overarching theme of the reconceptualization of scientific literacy. The effects of the two discourses in reconstituting scientific literacy
and the goals of science education will be briefly discussed in each of the analyses but a more cohesive analysis will be taken up in the following chapter.

**Science Education for Work – The Science Enterprise**

The NGSS labels science as “at the heart of United States’ ability to continue to innovate, lead, and create the jobs of the future” (NGSS, 2013a, p. 1). The NGSS document invokes a clear emphasis on science education and “college and career readiness.”

In the section of the NGSS titled “Why the Standards Matter,” four statements are provided as the rationale for the development of the standards. Two of them relate to the need for a revision of standards and setting out high expectations and goals in order for students to succeed. The other two mention the need to build an interest in STEM citing the “leaky K-12 STEM talent pipeline” as well as stating, “Implementing the NGSS will better prepare high school graduates for the rigors of college and careers” (NGSS, 2013a, p. 2). The importance of the NGSS seems to be primarily understood in facilitating success in college and careers in STEM fields.

As the NGSS lays out its rationale in its introduction section, the terms “career” (10) and “engineering” (27) are repeated frequently (as indicated in the parentheses) in relation to their importance to science education. Moreover, there is an extensive appendix titled “College and Career Readiness” that outlines the research that supports the need for an education system that prepares students for college and careers. In comparison, the need for science education as for all students is only iterated once in the first paragraph of the introduction. The term “scientific/science literacy” or
“scientifically literate” is not used at all in the Introduction section and in fact, is only stated 8 times in the entire NGSS document. This is intriguing, particularly considering that this document is likely to influence the way in which scientific literacy is viewed both in the United States and globally. This has been the case historically with previous national documents, such as *Science Literacy for All Americans* and the *National Science Education Standards* (AAAS, 1989; NRC, 1996).

**College and Career Readiness**

“Appendix C: College and Career Readiness” was analyzed to examine the foundational basis of developing a national science standards document that places an emphasis on stimulating interest in STEM.

There are clear links in the appendix made between the need for a strong background in science and postsecondary education, which is described as “critical to ensure the nation’s long-term economic security” (NGSS, 2013c, p. 1). Science education is presented as a central cog in the nation’s economic success, thereby seemingly justifying the incorporation of Science & Engineering Practices into the national science standards. This is concisely described in this excerpt:

“Economic and education statistics make it clear that the United States is not educating enough students who can succeed in a global information economy fueled by advances and innovation in science, engineering, and technology…. However, as the research studies referenced in this appendix indicate, there is a more productive path to follow in science education that entails linking important core content to the practices that scientists and engineers use as they go about their work. This shift in emphasis requires that we control the amount and kind of content, giving priority to powerful concepts that have currency because of their utility in explaining phenomena, predicting outcomes or displaying broad applicability in many fields…” (NGSS, 2013b, p.12)
While the link between education and the economy seems to be clearly presented in this statement, it is also important to examine the construction of the argument. The use of the following terms were used in describing the importance of science education: “statistics”, “global information economy”, “productive path”, “currency”, “advances”, “innovation”, “control” and “utility.” The content of the standards are seemingly connected to the idea of currency within the larger global landscape. This statement illustrates a clear emphasis on productivity and global competitiveness in the development of the NGSS. It reveals the role of the global economy within the educational landscape, which has led to an emphasis on internationally benchmarked content that allows nations to ensure their competitiveness in the global economy. The changing priorities within education are explicitly stated as the standards go on to identify that the best education is one that integrates content knowledge with the practices of scientists and engineers (NGSS, 2013c).

**Analysis - The Science Enterprise**

The NGSS is not subtle about its motivations for the creation of a standards document that outlines the necessary content and skills to be proficient in STEM fields. It outlines four key reasons for the necessity of the revised science standards: “reduction of the United States’ competitive economic edge, lagging achievement of US students, essential preparation of all careers in the modern workforce, and scientific and technological literacy for an educated society” (NGSS Lead States, 2013). Three of these “needs” for the NGSS link the importance of science education to the economic productivity of the nation, while the last relates to the needs of science in our daily lives.
(NGSS Lead States, 2013). This is clearly evident as the NGSS references the importance of competing in the “global information economy” and therefore choosing the knowledge and skills that would have “currency”. This seems to privilege the knowledge and skills that would be regarded as a form of capital in the global economy.

Investments in STEM fields are seen to be fundamental for economic and social development in modern society (NRC, 2011). The National Research Council (NRC, 2011, p. 3) has determined the nation’s workforce of scientists and engineers, comprising 4% of the population, will disproportionately create jobs for the other 96%. Although the NRC highlights the need for understanding of STEM at all job levels, there is a greater emphasis placed on the STEM education that is beneficial for individuals pursuing STEM fields.

Government initiatives, such as the $4.35 billion Race to the Top (RTTT) grant program allocated $650 million for STEM education development (Pierce, 2013, p. 37). Moreover, the basis of grant criteria has a greater preference for states that incorporate STEM education (Johnson, 2012). There has also been funding from business corporations for STEM education, which is particularly beneficial to them since these corporations have a stake in the economy.

The lead partners that contributed to the development of the NGSS were The National Research Council (NRC), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and Achieve. Achieve is described as, “an independent, nonpartisan, nonprofit education reform organization dedicated to working with states to raise academic standards and graduation
requirements, improve assessments, and strengthen accountability” (NGSS Lead States, 2013). However, some of the contributors for Achieve are Chevron, ExxonMobil, IBM, Microsoft, The Boeing Company, and JP Morgan Chase Foundation. In addition, the major sponsor of NGSS is the Carnegie Corporation of New York, with additional support from The GE Foundation, The Noyce Foundation, The Cisco Foundation and DuPont (NGSS Lead States, 2013). All of these foundations originate from corporations that seek to benefit from a STEM-focused science education. Therefore, the focus on college and career readiness in the NGSS may also be linked to the document’s partners and sponsors that were instrumental in its development.

In effect, the standards seemingly place a premium on a scientific literacy that produces human capital for global economic competition (Pierce, 2013, p. 114). A STEM-focused scientific literacy confines critical thinking to be oriented towards economic development and profit rather than active citizenship (Hodson, 2003). The NGSS encourages an understanding of a more neoliberal technoscience that fosters business-science partnerships such that science’s contribution to the world is judged in terms of how well ideas translate to profit (Bencze & Carter, 2011).

However, small-scale research has shown that the connection between science education and economic development is at best, inconclusive (Drori, 2000). Despite this, the need for improvements in science education in order to bolster the economy has become a dominant and powerful argument for scientific literacy. This has led to a narrowly defined scope of science education within the NGSS as one that is for college and career preparation in STEM fields. Moreover, the intertwinement of science
education and business has created a science enterprise, in which gains are measured in economic productivity.

**The Constitution of Technology**

“The interdependence of science—with its resulting discoveries and principles—and engineering—with its resulting technologies—includes a number of ideas about how the fields of science and engineering interrelate” (NGSS, 2013d, p. 1). In this statement, the NGSS positions science as a conduit for discoveries, which when applied through engineering, advance technology. Consequently, this provides scientists with new capabilities to explore the world. In this relationship, technology is an important mediator that allows for the interaction between science and engineering. Therefore, this section summarizes findings regarding how technology is identified, described, and related to other concepts in the NGSS.

The NGSS incorporated “The Influence of Engineering, Technology and Science on Society and the Natural World” as a crosscutting concept in the standards. The document identifies this inclusion as an effort to focus on science, technology, and society (STS) education. It outlines two core ideas of this STS-based crosscutting concept – one was the central role of technology on society and the environment, while the second considers “limits to growth imposed by human society and by the environment, which has limited supplies of certain non-renewable sources” (NGSS, 2013e, p. 1). These core ideas characterize technology as essential while positioning human society and environment as a limit to the growth of technology.
The NGSS does not explicitly include STS themes as core ideas or performance expectations, but rather incorporates them as crosscutting concepts that support performance expectation. Only 15% of the performance expectations show connection to STS themes. Table 4 shows instances of these connections represented in the performance expectations.

Three performance expectation (HS-LS2-7, HS-LS4-6 and HS-EES3-6) were not identified as STS themes by the NGSS but are included because their connection to STS themes seems apparent. This is particularly surprising as both HS-LS2-7 and HS-LS4-6 explicitly suggest an investigation into reducing the impacts of human activity. Perhaps the NGSS did not consider technology as central to these statements, but technology plays an essential role in urbanization and the building of dams, as stated in the clarification statement (not shown in table in consideration of space) of HS-LS2-7. HS-EES3-6 encourages the use of computational models to examine how the relationship among Earth systems is being influenced by human activity. Once again, the role of technology is not explicit in this statement. However, the increase in greenhouse gases is implicated in the clarification statement, which seemingly has clear connections to technology and industrialization. This calls to question whether the NGSS has a complete understanding of the tenets of STS education. In addition, the common thread in these statements is their reference to human activity. Technology is not explicitly implicated in any of them. In doing so, technology’s contribution to the impacts of human activity is essentially invisible
| Physical Science | HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.  
HS-PS4-2 Evaluate questions about the advantages of using a digital transmission and storage of information.  
HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. |
| Life Science | HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.  
HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity. |
| Earth and Space Science | HS-EES2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.  
HS-EES-3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.  
HS-EES-3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.  
HS-EES3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.  
HS-EES3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.  
HS-EES3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. |
Another method in the characterization of technology is the adoption of a neutral stance. The core tenets of the STS-based crosscutting concept as outlined by the NGSS are (NGSS, 2013f, p. 4):

- “Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications.
- Engineers continuously modify these systems to increase benefits while decreasing costs and risks.
- New technologies can have deep impacts on society and the environment, including some that were not anticipated.
- Analysis of costs and benefits is a critical aspect of decisions about technology.”

The contributions of technology are represented as essential to modern civilization. However any reference to the negative effects of technology are in the terms “deep impacts” and “unanticipated”, which do not necessarily have an undesirable connotation. Therefore, technology is viewed as having an overwhelmingly positive influence that is indispensable to society. As these are the tenets that guide STS themes throughout the NGSS, this characterization is consistent within other sections.

In addition, the impact of human activity in the NGSS is also mostly qualified in neutral terms. In searching for terms associated with “human”, there is only one instance when the NGSS addresses the “adverse impacts of human activity.” Moreover, technology is understood to be central in solving society’s problems. For example, two of the disciplinary code ideas in Earth and Space Science state,

“Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)
All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

Technology is seemingly considered the solution for solving the world’s sustainability issues, particularly in relating to reducing pollution and other challenges that threaten the environment. In addition, technology is identified as a factor in mitigating the risks of energy production and resource extraction, both processes which already heavily rely on technology. These statements suggest that environmental challenges have technological solutions.

The following are Nature of Science principles, a crosscutting concept within the NGSS, that are related to technology:

“Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.

Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.”

These statements illustrate that the NGSS works to establish a strict division between science and ethics, values, and decision-making. In creating this distinction, the NGSS calls for scientific neutrality. Thus, based on the NGSS’ conception of science knowledge, science and technology are considered value-free entities and do not inherently possess moral and ethical issues. Instead, these issues are considered to be external to them.
In summary, the characterization of technology in the NGSS is as a value-free entity that is vital to civilization as it tackles global environmental challenges, while mitigating the negative influences of human activity.

**Analysis – The Constitution of Technology**

The inclusion of engineering practices is novel to the standards and does some positive work by reimagining the study of science as technoscience (Sismondo, 2008). However, the NGSS is problematic in its constitution of technoscience as value-free and in identifying technology as a “fix” for society’s problems.

There is a sense of technological optimism in the NGSS. Technology is viewed as a solution to most of society’s challenges, particularly in relation to sustainability, which espouses a technocentric perspective (Papert, 1987). Technocentrism is a value system that believes in the power of technology to control and protect the environment (O’Riordan, 1995). Thus, it imposes a hierarchical set-up in which humans are placed at the top and the environment becomes a commodity that can be possessed and changed in order to suit the needs of humans. Moreover, “technological fixes” assume that we can continue with our lifestyle of exploiting the environment because these “fixes” exist.

Failing to realize the subjectivity of technology illustrates an entrenchment in technoscientism. It teaches that scientific knowledge is a result of objective analysis of data that is free from biases such as race, gender, culture, politics, economics, and so on (Bencze & Carter, 2011). As Nye (1990) illustrates, technology is a social activity: “someone makes it, someone owns it, some oppose it, many use it, and all interpret it” (pp. ix-x). In establishing a clear demarcation between technology and ethics, values and
decision making, the standards presents technology as inherently neutral and without agency. However, as Hodson (2003) and Harris (2010) noted, values are embedded in every part of our lives. This is more succinctly explained through Actor Network Theory (ANT), which states that nothing has an a priori distinction – everything comes into effect as a result of networks of actants. Therefore, any entity is constituted through its connection within its networks. This is particularly true for technology, which is commonly “blackboxed” to disguise the network of actants, thereby reducing it to merely its outputs and inputs. In doing so, considerations such as politics, economics, corporate interests, societal impacts and the values and morals that encompass these aspects in the networks that produce technology become erased. This allows technology to be presented as a neutral entity without any ties. Therefore, implying that technology and technoscience do not possess values and morals results in an uncritical acceptance of technology and its place in society. This is particularly beneficial for organizations and corporations who develop and profit from technology. They can then frame problems in technical ways (ie. risks and benefits), masking social, moral and ethical dilemmas (Jasanoff, 2003).

There is a dearth of possibilities in the NGSS for examining the ethical and societal implications of science and technology. For example, in the Life Science discipline, core ideas or performance expectations do not reference or allude to biotechnology (ie. GMO, gene therapy, etc.). In the Physical Science discipline, while there are references to nuclear fission and fusion, there are no direction mentions in regards to the effects of using nuclear energy or the detrimental effects of nuclear
weapons. In excluding these possibilities from the standards, the NGSS avoids any controversial subjects, particularly as it is clear in drawing a line between ethics and morals and science.

In fact, most of the effects of human activities and technologies are framed in neutral ways that eliminate any sense of responsibility (for individuals, corporations and governments). This is in line with some scholars’ assessment of the STEM movement’s failure in addressing the broader sociocultural and political needs of global communities. Instead, there is a myopic focus on technocratic issues (Zeidler, 2014). The NGSS does not encourage stewardship of the environment or allude to any sense of social responsibility. This is likely because environmental problems are seen as external to us, but they are, in fact, a social problem (Hodson, 2003). As discussed before, technology is a product of networks. We are integral to these networks as we use them and are influenced by them. According to ANT, those who are involved in the development of technology are called “sociologist engineers” (Callon, 1987). In the process of technical innovation, we are simultaneously constructing technology and the social world. Technology changes how we perceive our world and reforms our relationships. Without interrogating these interactions and the actants within them, actants will not be held accountable and will continue to exist and shape our environment in detrimental ways.
3. Equity in the NGSS – A deficit framework

Accommodations for interest in science

The NGSS declares, “All students – whether they become technicians in a hospital, workers in a high tech manufacturing facility, or Ph.D researchers – must have a solid K-12 science education” (NGSS, 2013a, p. 1). In an effort to ensure this, the NGSS must be accessible to all students, regardless of race, gender, ethnicity, socioeconomic status or interest in science. Interest in science is important to consider because while it would be ideal for students to continue with science from K-12, that is unlikely and statistically not the case. Secondary education in the United States separates science disciplines starting in grade nine. In most states, students are required to complete three courses in science in order to graduate. Available science courses vary in states, districts and schools but examples include: biology, chemistry, physics, environmental science, and earth science (NGSS, 2013c).

Thus, stating that all students must have a K-12 science education is unrealistic and doesn’t account for students who choose to discontinue their science education early on in high school. In addressing this concern, the NGSS states (NGSS, 2013d, p. 2):

“all students should be held accountable for demonstrating their achievement of all performance expectations—deserves special attention because it is a fundamental departure from prior standards documents, especially at the high school level where it has become customary for students to take courses in some but not all science disciplines. The NGSS takes the position that a scientifically literate person understands and is able to apply core ideas in each of the major science disciplines, and that they gain experience in the practices of science and engineering and crosscutting concepts. In order for this to be feasible the writing team has limited the core ideas included in the performance expectations to just those listed in the Framework.”

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Limiting the core ideas included in the performance expectations (which earlier was shown to not be the case) fails to address the concern that students may not take courses in all science disciplines. This is particularly a problem within the domain of Earth and Space Sciences. Since most states require 3 science courses, students typically enroll in biology, chemistry, and physics (NGSS, 2013d). The NGSS identifies this problem and provides suggestions for integrating these performance expectations into the existing three courses, which would necessitate a restructuring of science curriculum.

By not fully addressing the problem of student interest and the structuring of the NGSS content, the standards fail to accommodate for students that do not choose a path in science education. Therefore, as these students will not be able to meet all the performance expectations, they may lack a comprehensive and cohesive science education, as they will not have the opportunity to develop the disciplinary core ideas over four years.

**All Standards, All Students**

This section will explore how the NGSS addresses equity in reference to the “non-dominant” groups, particularly in “Appendix D – All Standards, All Students”. “Non-dominant” groups are identified by the NGSS as those who do not benefit from institutionalized privilege and have long been marginalized in the education system (NGSS, 2013d). NGSS identifies seven “non-dominant groups”: economically disadvantaged students, students from major racial and ethnic groups, students with disabilities, students with limited English proficiency, girls, students in alternative education programs, gifted and talented students (NGSS, 2013d, p.3). In addition to the
appendix, the NGSS presents seven individual case studies that outline strategies for implementation of the NGSS in the classroom by presenting vignettes and relevant research.

In describing the non-dominant groups in the appendix, the adverb “traditionally” is employed 11 times, i.e., “traditionally underserved.” In each of these cases, the adverb has been followed by these terms: “struggled”, “underserved”, “marginalized”, “alienated from science”, “underrepresented”, and “have not considered science as relevant to their lives”. While the word traditionally is used to describe these groups, there is never an explanation as to why this tradition of marginalization persists.

The NGSS notes that there is increasing diversity within the United States but highlights that achievement gaps continue to persist. Moreover, the terms ‘increasingly diverse’, ‘increase of student diversity’ and ‘changing demographics’ are frequently employed to describe the student population in the US. The use of these terms in describing how these groups are failing to achieve, positions diversity as a problem in the US education system.

In addition, the NGSS document states, “...reports consistently highlight that when provided with equitable learning opportunities, students from diverse backgrounds are capable of engaging in scientific practices and constructing meaning in both science classroom and informal setting” (NGSS, 2013d, p. 4). This statement should be implicitly understood in any institution, without the need for reports and credible research to confirm it. It seems to suggest that the fact that students are “capable” is a novel finding. It also appears to disguise the fact that equitable learning opportunities
may not be the norm that these students experience, considering the document states it as a novel finding. Rather, we should question: why hasn’t it always been the case that students are provided equitable learning opportunities?

The NGSS reports that the standards require “increased cognitive expectations” to make connections with science & engineering practices and crosscutting concepts. It goes on to state, “Making such connections has typically been expected only of ‘advanced’, ‘gifted’, or ‘honors’ students….The goal of this chapter and the case studies is to demonstrate that the NGSS are extended to all students” (NGSS, 2013d, p.1). This statement illustrates the previously held low expectations for non-dominant groups and how the NGSS attempts to change this pattern by extending these high “cognitive expectations” to all students.

In addition, the NGSS addresses the equity issue with an emphasis on teaching practices as it states, “teachers must make instructional shifts to enable all students to be college and career ready” (NGSS, 2013d, p.4). Thus, the onus falls on the teacher to employ effective strategies in order to meet the expectations of the NGSS. Table 5 outlines the pedagogical approaches identified and illustrated for non-dominant groups as presented through vignettes in the case studies.

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Table 5. Pedagogical Approaches for Non-Dominant Groups in the NGSS

<table>
<thead>
<tr>
<th>Non-dominant” groups</th>
<th>Effective Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economically Disadvantaged Students</strong></td>
<td>(1) connecting science education to students’ sense of “place” as physical, historical, and sociocultural dimensions in their community;</td>
</tr>
<tr>
<td></td>
<td>(2) applying students’ “funds of knowledge” and cultural practices</td>
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<tr>
<td></td>
<td>(3) using project-based science learning centered on authentic questions and activities that matter to students.</td>
</tr>
<tr>
<td><strong>Students from Racial and Ethnic Groups</strong></td>
<td>(1) culturally relevant pedagogy</td>
</tr>
<tr>
<td></td>
<td>(2) community involvement and social activism</td>
</tr>
<tr>
<td></td>
<td>(3) multiple representation and multimodal experiences</td>
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<td></td>
<td>(4) school support systems including role models and mentors of similar racial or ethnic backgrounds.</td>
</tr>
<tr>
<td><strong>Students with Disabilities</strong></td>
<td>(1) multiple means of representation</td>
</tr>
<tr>
<td></td>
<td>(2) multiple means of action and expression</td>
</tr>
<tr>
<td></td>
<td>(3) multiple means of engagement</td>
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<tr>
<td><strong>English Language Learners</strong></td>
<td>(1) literacy strategies for all students</td>
</tr>
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<td></td>
<td>(2) language support strategies with English language learners</td>
</tr>
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<td></td>
<td>(3) discourse strategies with English language learners</td>
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<td></td>
<td>(4) home language support</td>
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<td></td>
<td>(5) home culture connections.</td>
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<td><strong>Girls</strong></td>
<td>(1) instructional strategies</td>
</tr>
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<td></td>
<td>(2) curricular decisions</td>
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<td></td>
<td>(3) classroom and school structure.</td>
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<tr>
<td><strong>Students in Alternative Education</strong></td>
<td>(1) structured after-school opportunities</td>
</tr>
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<td></td>
<td>(2) family outreach</td>
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<td></td>
<td>(3) life skills training</td>
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<td>(4) safe learning environment</td>
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<td></td>
<td>(5) individualized academic support.</td>
</tr>
<tr>
<td><strong>Gifted and Talented Students</strong></td>
<td>(1) fast pacing</td>
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<td></td>
<td>(2) different levels of challenge (including differentiation of content)</td>
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<td></td>
<td>(3) opportunities for self-direction</td>
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<td></td>
<td>(4) strategic grouping.</td>
</tr>
</tbody>
</table>

While there are concerted efforts to include culturally relevant pedagogical approaches, some of them are poorly implemented in the vignettes. For example, in one of the vignettes, a teacher referred to a crushed can in their neighbourhood in order to
teach the concepts of gases and pressure. This was identified as a connection to students’ sense of place. Addressing students’ sense of place means taking into account a person’s cognitive and affective understandings and associations of a place they inhabit (Lim & Calabrese Barton, 2010). It is not merely a discussion of geography. The example presented is clearly not an authentic connection, but rather a superficial connection that is tacked onto content knowledge in classrooms.

Other approaches created problematic representations of students and their families. This was most visible in the approaches that address the inequities in alternative schools. The NGSS identifies alternative schools as non-traditional models, which may include charters, magnets, residential, court, and public alternative schools. One of the suggested strategies in making the NGSS more accessible in alternative schools was to incorporate life skills training, which includes behaviour management. In addition, the family outreach was encouraged in order to, “strengthen families by offering classes on communication, parenting, and student academic support.” Behavioural management and family outreach (including parenting classes) were not identified as a pedagogical approaches for other non-dominant groups. This creates a concerning depiction of students in alternative schools and reinforces stereotypes.

**Analysis – A Deficit Framework**

The NGSS is a national science standard document that will be adopted by the states and will influence the discourse of science education. However, some students will receive differential application of these standards because the NGSS makes no accommodation for differing interests in science that may preclude them from pursuing
science education until Grade 12. It seems to be clear that they are not the target audience of the NGSS. Therefore, those who are not “ideal”, will likely not be encouraged to engage with science. As a result, there is a question as to the quality of science education for students who do not pursue science through to grade 12. Will they be able to use and critique science knowledge in a manner that allows the capabilities of effective decision-making in public science-related issues?

In accordance with the findings in the NGSS, the ideal learner is positioned as an individual who will pursue science in order to enter STEM fields, thereby producing human capital for global economic competition (Pierce, 2013, p. 114). Moreover, there is little emphasis on creating a scientifically literate citizen, as most of the standards are STEM-specific without addressing the broader societal issues that students will have to face in their future.

In modern societies, citizenship is an exercise of choice – one can choose to participate or not, or participate in some issues while being passive in others. Similarly, equity in the NGSS is framed in terms of an opportunity to participate (similar to economic market models) instead of an authentically democratic education (Tobin, 2011). Students are given the opportunity for a K-12 science education in order to pursue a STEM career. The students who choose to opt out of this opportunity are likely to engage in what Levinson (2010) describes as a deficit model of democratic participation. In a deficit model, individuals do not have the technical knowledge to engage in controversial public issues but they can be taught about the issues, serving as a “cognitive container” (Levinson, 2010). As a cognitive container, they are passive
knowledge consumers. Generally, they are more likely to support government and corporate funding for science programs that lead to economic productivity (Wynne, 1995). Thus, a deficit model limits their participation and they are unlikely to actively contribute to the democratic process.

The fundamental problem of standards is that it espouses a “one-size-fits-all” rhetoric, which dictates the need for all individuals to learn a body of scientific knowledge that is deemed essential. The rhetoric suggests that if all students learn a prescribed science, then everyone will be equal (Calabrese Barton & Osborne, 2001, p. 12). While the NGSS addresses how to accommodate the standards for students who are traditionally marginalized (“non-dominant groups”), the onus falls on teacher to provide effective strategies to meet the expectations of the standards. The NGSS does not appear to take responsibility for creating a standards document that mediates the creation of a democratic science education that meets the needs of all students, as opposed to just those that pursue STEM careers.

Addressing inequities within these “non-dominant” groups is a double-edged sword. While it is important to identify the groups that face inequities within the education system, doing so at times creates the illusion that the issue lies within the group and not the system itself. The NGSS confounds the two and labels these groups as different in their capabilities to achieve the same standards, thereby advocating a deficit ideology.

Deficit ideology justifies outcome inequalities— for example, standardized test scores—as deficiencies within disenfranchised communities (Weiner, 2006; Yosso,
In doing so, it discounts factors such as race, ethnicity, gender, and socioeconomic status that allow some individuals greater access to schooling (Brandon, 2003). For example, the NGSS continued the use of terms such as traditionally underserved, marginalized, or alienated without ever entering a discussion addressing why this is the tradition exists. Little was done to examine the systemic inequities that result in achievement gaps. Instead, the blame was shifted to the students and their culture (Ladson-Billings, 2006). Furthermore, the notion of the achievement gap is predicated on the basis of standardized test scores, which fail to realize that the playing field is already ‘savagely’ unlevel (Kozol, 2012).

Deficit ideology is predicated on beliefs that inequalities result from intellectual and cultural deficiencies inherent to communities of disenfranchised individuals, as opposed to unjust social conditions (Brandon, 2003; Gorski, 2008, Yosso, 2005). Common and traditional strategies aiming to close the “achievement” gap are informed by deficit ideology, such as offering mentors to students’ families because of the assumption that the parents don’t care about education (Weiner, 2003). This was found in the NGSS as it suggested parenting classes as part of family outreach programs for students in alternative schools.

The NGSS operates on this deficit ideology that is driven by the myth of meritocracy. In advocating for a standards document that prepares students for college and careers, it states:

“Postsecondary education is now seen as critical to ensure the nation’s long-term economic security, to respond to the transformation in both the nature and number of
current and projected jobs, and to enable social mobility... The Organisation for
Economic Co-operation and Development (OECD) observes that children of less-
educated parents in the United States have a tougher time climbing the educational ladder
than in almost any other developed country (OECD, 2012a, p. 102). The American
dream that one’s birth circumstances do not control one’s destiny is fast slipping away.”
(NGSS, 2013c, p. 1)

The NGSS cites the preservation of the American dream as a foundational basis
for developing a standards document that has a focus on the preparation of students for
college and careers. In doing so, it creates the notion that the need for STEM-focused
education system will restore meritocracy.

Schooling practices, in general, legitimize white and middle-class experiences
and in order to succeed, students must conform to culturally specific ways of knowing.
Marginalized students in urban contexts often experience a conflict between the home
and school culture, which serves to further exclude them from the culture of science.
Therefore, there is the sense that the students need to be assimilated into the existing
culture of schooling, instead of examining the structures that disenfranchise them
(Calabrese Barton & Osborne, 2001). Thus, the rhetoric of “science for all” employs
equality as a mask to conveniently ignore the fundamental structures of power in
schooling and science that results in the exclusion of marginalized individuals.
Chapter 5
Discussion & Conclusions

This qualitative study conducted a critical discourse analysis of the Next Generation Science Standards in an effort to explore and review the discourses of scientific literacy operating in the United States, with an additional emphasis on how equity is addressed within these discourses. This chapter will summarize the findings and analysis of the study and situate it within the overarching theories of science education.

Neoliberalism is the Dominant Social Imaginary

To situate the context of this study, an understanding of neoliberalism is necessary. Neoliberalism is the theory that well-being of humans is best served by fostering individual freedoms and encouraging entrepreneurship through privatization and free markets (Harvey, 2005). While there are reduced regulations in the market and a greater emphasis on individual responsibility, it also allows for intervention by government and supranational organizations to achieve strategic goals. Supranational organizations, such as the International Monetary Fund and the World Bank are multinational organizations that are loyal to global financiers or corporations, as opposed to nations (McMutry, 2013). It is important to note that the definition of neoliberalism is contested and there are some critiques that also question its history.

Neoliberalism has become so diffuse that it has generalized the economic form to all human interactions (Burchell, 1993). It shapes how we imagine our world (values, relations, subjectivities, identities, etc.) and ourselves within it – thereby shaping our
social imaginary (Taylor, 2004). It has influenced the way people experience and interpret social relations. In doing so, it constructs new subject positions and identities for people and dictates how they live their lives.

**Neoliberalism through an Actor Network Theory Lens**

Actor Network Theory (ANT) explains the permeation of neoliberalism by drawing on the interaction of networks consisting of governments, supranational organizations, corporations, public service institutions (i.e. education, health care) media, etc. According to ANT, entities (both human and non-human) only gain significance through interactions within a network. Therefore, neoliberalism is generated through the relations in multiple dynamic networks. The pervasive nature of neoliberalism gives the illusion of a stable reality - implying that all the actants and interactions are secured (Hassard et al., 1999). It is hard to imagine a reality in which neoliberalism does not operate. However, there is always work to be done in order for networks to be durable since socio-material relations are dynamic and are constantly shifting.

Maintaining a relatively stable interconnected network involves power. As opposed to traditional views of power, ANT does not conceive of power as a possession. An entity does not possess power. Instead, power is an effect resulting from the entities that are networked (Law, 1992). This notion of productive power is consistent with Foucault’s (1991) idea of governmentality.

Foucault’s concept of governmentality examines how an individual’s self-control is linked to political rule and economic activity (Lemke, 2002). He seeks to analyze the connections between what he calls “technologies of the self” and “technologies of
domination” to understand how the state and the individual are constituted. In describing
governmentality, Focault (1993, p. 103) states:

“…he has to take into account the interaction between those two types of
techniques – techniques of domination and techniques of the self. He has to take into
account the points where the technologies of domination of individuals over one another
have recourse to processes by which the individual acts upon himself. And conversely,
he has to take into account the points where the techniques of the self are integrated into
structures of coercion and domination.”

While an individual may believe they are self-governed, their actions are a result
of the technologies of domination, such as forms of media (ie. news, sports, etc.), which
can spread neoliberal messages of individualism and consumption. Therefore,
neoliberalism propels an individual to act by facilitating the internalization of neoliberal
principles.

Neoliberal governmentality allows for the ideology of neoliberalism to be
disseminated. This can be explained by Callon’s (1986) concept of translation within
Actor Network Theory. Translations involves different actants with varying interests that
coordinate together towards a common cause through negotiations of these interests. In
doing so, they become enrolled in this cause whereby they develop new identities and
behaviours in support of this cause. As this network becomes more durable through the
recruitment of other actants and networks, it can be extended to other locations and
domains (Fenwick, 2010). Thus, neoliberalism becomes translated from the networks of
governments and market forces to institutions, such as schools, enrolling them within the
larger network of neoliberalism. This fundamentally reforms education systems, reshaping them both structurally and discursively to create a market model system of education. Therefore, everyone becomes reduced to positions of suppliers and customers.

**Neoliberalism and Education**

In education, we are seeing the effects of neoliberal reforms such as the No Child Left Behind (NCLB) legislation and Race to the Top (RTTT) initiative in the United States. They are governing schools through policies of competition that punish those who fail. These reforms are examples of the coupling of neoliberal policies of marketization coupled with neoconservative practices of regulation through national curriculum and testing (Apple, 2001). Neoconservatism works alongside neoliberalism to preserve traditional forms of privilege through the restoration of class power (Harvey, 2005).

Neoconservative practices of increased accountability through achievement standards and standardized testing works in parallel with neoliberal policies to ensure the maintenance of the neoliberal network (Carter, 2005). This culture and mode of regulation has been termed “performativity” by Stephen Ball (2003). It is a means of control based on a system of rewards and sanctions (both material and symbolic). The “performances” of individuals and organizations are representative of their productivity and value. Standardization is an important component of performativity as it allows for a quantitative representation of education, reducing education to a commodity (Ball, 2003). Neoconservative practices operate at the global level through organizations such as the OECD that creates internationally benchmarked standards to promote national comparisons of educational achievement (DeBoer, 2011). These effects are then felt at
the national and local level through educational reforms (ie. standards) that are enacted in an effort to remain globally competitive. The most recent reform in science education in the United States is the development of the Next Generation Science Standards. The next section discusses the place of the NGSS within science education by revisiting the first research aim of this study.

**In what ways does the NGSS shape the discourse of science literacy and science education as a whole within the nation and elsewhere?**

STEM education is the new wave of scientific literacy that aims to prepare students for their future in a rapidly changing global landscape. The NGSS states that the aim of the document is to fix the “leaky STEM talent pipeline” in order to provide better preparation for college and careers (NGSS, 2013a). This illustrates an emphasis on college and career readiness and the need to stimulate interest in STEM, which is further supported through the inclusion of science and engineering practices. The issue does not lie in encouraging students to pursue STEM fields but it becomes problematic when it encompasses the entire discourse of the document. This study has illustrated that the standards in the NGSS are prescribed and privileges disciplinary content knowledge. If such technical knowledge is a representation of how the standards will be presented in classrooms, this may prove to be problematic for those individuals that cannot negotiate the abstractions of this language (Knain, 2005). Its rigid nature is also illustrated in the provision of assessment boundaries that stipulates the measurable outcomes of student learning. The practical applications of science represented within the NGSS focuses on a prescriptive non-normative (data gathering, developing models, etc.) practice of science.
This is consistent with research that shows that STEM education has a technocratic focus with little attention paid to sociocultural contexts (Zeidler, 2014).

An authoritarian standards document is likely to impede democratic participation in the classroom because of its strict adherence to what students should know and how they can prove their proficiency for the purposes of assessment. In doing so, it confounds scientific literacy as a mastery of knowledge and skills in a K-12 education system.

The NGSS purports to be novel in the inclusion of engineering practices so as to make science learning more relevant and meaningful. While the inclusion of technological design has been found to improve science learning, it is reliant on an authentic engagement with science (Roth, 2001). The content related to engineering and technology in the NGSS focuses on design and innovation as opposed to examining the sociocultural and political effects. Moreover, technology is constituted as inherently without moral or ethical dilemmas, thereby failing to address that technology is the product of networks of actants with motivations. This sense of technological neutrality encourages the passive acceptance of technological advances in society without any critical reflection of its nature and consequences. This positions students as passive knowledge consumers who may develop into compliant workers that are uncritical of their consumption (Giroux & Giroux, 2006).

Moreover, the NGSS references the “global information economy” and the selection of knowledge and skills that have “currency” in current society. Thus, the selection of disciplinary knowledge found in the NGSS promotes the education of a select few (knowledge producers) who will become scientists & engineers. This is
supported by the National Research Council who has determined the nation’s workforce of scientists and engineers, comprising 4% of the population, will disproportionately create jobs for the other 96% (2011, p.3). Thus, NGSS privileges the 4% at the detriment of the 96%.

Science education standards (and standards in general) are *black-boxed* – they are considered to be neutral but are in fact a result of negotiations of power. The NGSS appears to be part of a movement within STEM that works to reconceptualizes scientific literacy as “education for work” – a discourse that serves neoliberal motivations. It positions students as abilities machines (Foucault, 2010). They are seen as human capital destined to produce profit for the national economy. This produces an extraction model of schooling where schools can be mined for human capital (Pierce, 2013). In addition, it divides students into knowledge producers and knowledge consumers, with schooling privileging the education of the former.

Standards are part of neoconservative practices that emphasize increased regulation through assessment of performativities (Apple, 2001; Ball, 2003). In doing so, they preserve traditional forms of privilege and marginalize democratic agendas (Carter, 2005). Neo-conservatism promotes *knowledge economies* where a select few (the elite) are active knowledge producers, while the majority become passive knowledge consumers.
How does NGSS promote a democratic education (ie. how does it address equity?)

As discussed in the previous section, the NGSS seems to privilege the education of knowledge producers (ie. scientists & engineers). This creates a culture of exclusion in which knowledge consumers do not have access to and/or benefit from the “official” knowledge in schools because of existing inequalities in schooling practices. Therefore, they are excluded from the networks of knowledge producers because their “cultural capital” is not recognized in school spaces (Bourdieu, 1986).

A “culture of power” is created in which the values, beliefs, and experiences of certain groups of people (usually white, middle and upper class, male, heterosexual) are privileged over others, thus creating a hierarchy in society (Delpit, 1988). The “culture of power” pervades every social structure in society, including schooling. The structures of schooling create exclusionary practices and result in the marginalization of students, as they are unable to access the culture of power. In pertaining to scientific literacy, the “culture of power” privileges certain ways of knowing and doing science that is only accessible to the privileged groups, while others are marginalized from participating in the culture of science. In effect, students learn who is capable of doing science by making connections in the types of out-of-school experiences that are valued in the classroom (Calabrese Barton & Yang, 2000). Thus, this culture of power ultimately reproduces the existing class structure (Anyon, 1980).

However, this “culture of power” fails to be explicitly recognized since society functions on the myth of meritocracy and on the promise of social mobility. Meritocracy
is explicitly enacted in the NGSS as it references that the “American dream” is slowly slipping away because schooling is not promoting social mobility (NGSS, 2013c). While this assertion illustrates a level of awareness, it goes onto state that the restoration of social mobility can be attained by better preparing students for the future by creating a standards document that facilitates better preparation for college & careers. This fails to address the fundamental structures that contribute to the failure of social mobility and proves detrimental in how the NGSS addresses inequities in science education.

The NGSS notes the achievement gap problem between dominant and non-dominant group, however, it does so within a deficit ideology. Therefore, the inequities in achievement are not seen as a problem within science education or the structures of schooling but as a deficit within the students and their culture. Instead of creating accommodations within the standards that allow for democratic engagement, this responsibility is left to teachers to ensure that all students meet the same expectations. This is a form of assimilation that fails to account for student diversity. However, if student fail to assimilate and achieve the same standard, they are seen as inferior (Apple, 1990). This is a result of the myth of meritocracy within the NGSS that is based on the erroneous belief that if all students learn science, they will be equal. It is a byproduct of a “one-size-fits-all” approach to science education.

The myth of the achievement gap is predicated on standardized testing, which fails to take into consideration that the playing field is “savagely” unlevel (Kozol, 2012). The NGSS is an actant within the network of standardized testing since tests will be written based on the NGSS standards. Thus, in trusting a system of testing that fails to
consider existing inequities only compounds the problem. It results in further marginalization of non-dominant groups through practices such as tracking (Anyon, 1980; Oakes, 1985; Page, 1991). Research has shown that given the pressure of these reforms, more of these students are marginalized and pushed out the education system and into the school-to-prison pipeline (Christle, Jolivette, Nelson, 2005). Thus, the established structures of schooling play a role in reproducing the inequities of race/ethnicity, social class, and gender.

Standards are a part of selective tradition because they represent one group’s definition of legitimate knowledge, which becomes official knowledge. It ensures those in positions of power maintain their economic and cultural superiority (Apple, 1993). The NGSS appears to legitimize the knowledge espoused by the STEM movement. It privileges a market model of education, where the needs of the individual are outweighed against the collective. In addition, equity becomes the opportunity to participate, much like the free market (Tobin, 2011).

The disparities created between the knowledge producers and consumers begin in schools, where students from advantaged homes are able to benefit from the culture of schooling due to the privileging of their cultural capital (Bourdieu, 1986). The rest find themselves marginalized and are unable to access the networks of power. They are ‘othered’ and their othering is justified through the ideological myth of meritocracy, which ignores the fundamental structures of power that operate in schools to benefit the elite.
Conclusions & Implications

This study examined the role of the NGSS in the discourses that it created within science education and how it addressed the concerns of equity. Analysis revealed an emphasis on a STEM education that works to create networks of exclusion by privileging science education that favours the production of an elite few - knowledge producers. The rest are relegated to become passive and uncritical knowledge consumers.

The NGSS is what Latour (1987) referred to as an “immutable mobiles”, which is part of a larger network (ie. neoliberalism) They function as delegates of this network and extend their power into different spaces by working to translate entities in ways that enroll them into the network. Some of these immutable mobiles become “obligatory points of passage”, a central entity through which all relations must flow through at some point. The NGSS is an obligatory point of passage for science education in the United States. State curricula, standardized tests, classroom teaching practices, just to name a few will all flow through the standards. The NGSS shapes the discourses of science education by reconceptualizing scientific literacy and in doing so, it constructs the relationship individuals have with science and technology and as an extension, their relationship to the world. In doing so, it functions as an actant in reproducing the status quo. Thus, the NGSS and other documents found within the neoliberal network are technologies of domination that aim to recreate the world where individualism is prized over the collective good. Therefore, its presence in the education system will work to sustain the inequities of neoliberalism.
It is clear that there is a need to interrogate and redefine what constitutes science, so that a just and democratic science education can be created. Freire noted the importance of critical consciousness of the oppressive structures, so that they can be transformed (1970/2004). However, it is not enough to become conscious of the oppressive structures, but rather, educators need to interrogate the structures in place and use science education as a form of social justice to overcome the oppressive conditions. While large scale reform shifts are unlikely, there is a need to create alternative networks that counter the effects of STEM education that economizes education. There are already been work done in this regard through STSE and SSI approaches to science education. It is through these approaches that social injustices associated with the schooling of science can be uncovered so that resistance is possible. This is the only way in which we can move towards a transformative and democratic science education that empowers students.
References


Appendix

An example of a standard from the Next Generation Science Standards.

**MS-PS3 Energy**

Students who demonstrate understanding can:

- **MS-PS3-1.** Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. (Clarification Statement: Emphasis is on descriptions of relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.)

- **MS-PS3-2.** Develop a model to describe when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. (Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of systems with energy that changes due to interactions at a distance could include: the Earth and either a solar system at any two positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classroom's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.)

- **MS-PS3-3.** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.]

- **MS-PS3-4.** Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. (Clarification Statement: Examples of investigations could include comparing that water temperatures alter different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.)

- **MS-PS3-5.** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. (Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.)

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

**Science and Engineering Practices**
- Developing and Using Models
  - Modeling in 6-8 builds on K-5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Planning and Carrying Out Investigations
  - Plan and conduct investigations to answer questions or test solutions to problems in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Analyzing and Interpreting Data
  - Analyzing data in 6-8 builds on K-5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Engaging in Argument from Evidence
  - Engaging in argument from evidence in 6-8 builds on K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed worlds.

**Disciplinary Core Ideas**

- **PS3.A: Definitions of Energy**
  - Motion energy is property called kinetic energy; it is proportional to the mass of the moving object and varies with the square of its speed. (MS-PS3-1)
  - A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2)
  - Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the type, states, and amounts of matter present. (MS-PS3-3

- **PS3.B: Conservation of Energy and Energy Transfer**
  - When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-3)
  - The amount of energy transferred to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (MS-PS3-4)
  - Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-5)

- **PS3.C: Relationship Between Energy and Forces**
  - When two objects interact, each one exerts a force on the other that can cause energy to be transferred from one to the other. (MS-PS3-4)

**Crosscutting Concepts**

- Scale, Proportion, and Quantity
  - Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-3)

- Energy and Matter
  - Energy may take different forms (e.g., energy in foods, thermal energy, energy of motion). (MS-PS3-5)
  - The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3)

- **ETS1A: Defining and Delimiting an Engineering Problem**
  - The more precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (secondary to MS-PS3-2)

- **ETS1B: Developing Possible Solutions**
  - A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (secondary to MS-PS3-2)