The NGSS and the Historical Direction of Science Education Reform

Lesley J. Shapiro
Classical High School
Rudolf V. Kraus
Rhode Island College

Abstract

The Next Generation Science Standards (NGSS) claim to be an evolution of previous work. Yet prominent voices in the science education community argue that they are a revolution. This study sought to examine these competing claims by analyzing an older middle school science curriculum through the lens of the NGSS. This analysis demonstrates that substantial alignment between the NGSS and older curricula can and does occur. There have been historically important precursors to reform-based science teaching and recognizing this more complex history may help us to advocate for better science education for all students.

Introduction

The name 'Next Generation Science Standards (NGSS)' is meant to imply that these standards are a continuation of previous practice, refined for a new generation of teachers and students. Both the NGSS document itself and *A Framework for K-12 Science Education* argue that these new standards are an evolution of previous work (National Research Council [NRC], 2012; NGSS Lead States, 2013). However, intent is not the same as execution. Some of the discussions around the NGSS portray the NGSS as a historic and significant shift in practice (Yager, 2015). Some of this rhetoric comes from people deeply involved in the creation of the NGSS (Bybee, 2014; Pruitt, 2015). These positions cannot both be true; either the NGSS is a significant break from previous practice, or it is not.

Professional organizations of science teachers and science teacher educators billed the NGSS as revolutionary. The National Science Teachers Association (NSTA) spent the months leading up to the release of the NGSS revving up anticipation using language such as "true paradigm shift" (Metts, 2013, p. 6; Kuhn, 1967) and highlighting feature articles which outlined how the NGSS were different while at the same limiting or downplaying what was the same. Concurrently, in conjunction with NSTA, the Association of Science Teacher Educators (ASTE) revised the guidelines for science teacher preparation programs. The difference and newness of the standards was highlighted everywhere while the elements of continuity from prior practice were downplayed.

Shortly after the release of the NGSS, the major curriculum publishers began hawking brand-new supposedly NGSS-aligned curricula. The exhibit halls at all the national and state-level professional conferences of science teachers were awash with textbooks, lab materials, and other ancillaries seemingly overnight (NSTA, 2013; NSTA, 2014, NSTA 2015). Teachers across the United States were bombarded at their schools and in communications from professional organizations with advertisements and samples encouraging them to adopt new curricula.

If the NGSS are part of a continuous direction of reform then previous reform-based curricula will largely align, revealing a substantial pool of resources for teachers and students. This leads us to the questions: (1) Do the conceptual shifts outlined in NGSS Appendix A: Conceptual Shifts break from previous practice or continue it? (2) What happens when the NGSS are superimposed onto older science education curricula?

We elected to conduct a textbook analysis of an older middle school science curriculum to determine the alignment between it and the NGSS. Our hypothesis, which aligns to the assertions in the NGSS document, is that the NGSS are a continuation of previous reform efforts in science education. A relatively poor alignment would indicate that the NGSS are a significant departure, thus refuting our hypothesis. Further, tight alignment between the NGSS and older curriculum materials could open a trove of resources for teachers to mine as they seek to implement NGSS-aligned instruction. While a plethora of resources claiming to be aligned to the NGSS are being marketed to teachers, these resources are expensive and questions about their alignment to the standards exist (EdReports.org, 2017-2019; Sawchuk, 2019). Fulmer, Tanas, and Weiss (2018), call attention to the innovative structure of the NGSS and the varied ways in which alignment is possible and their review reveals a lack of a consistent method of alignment.

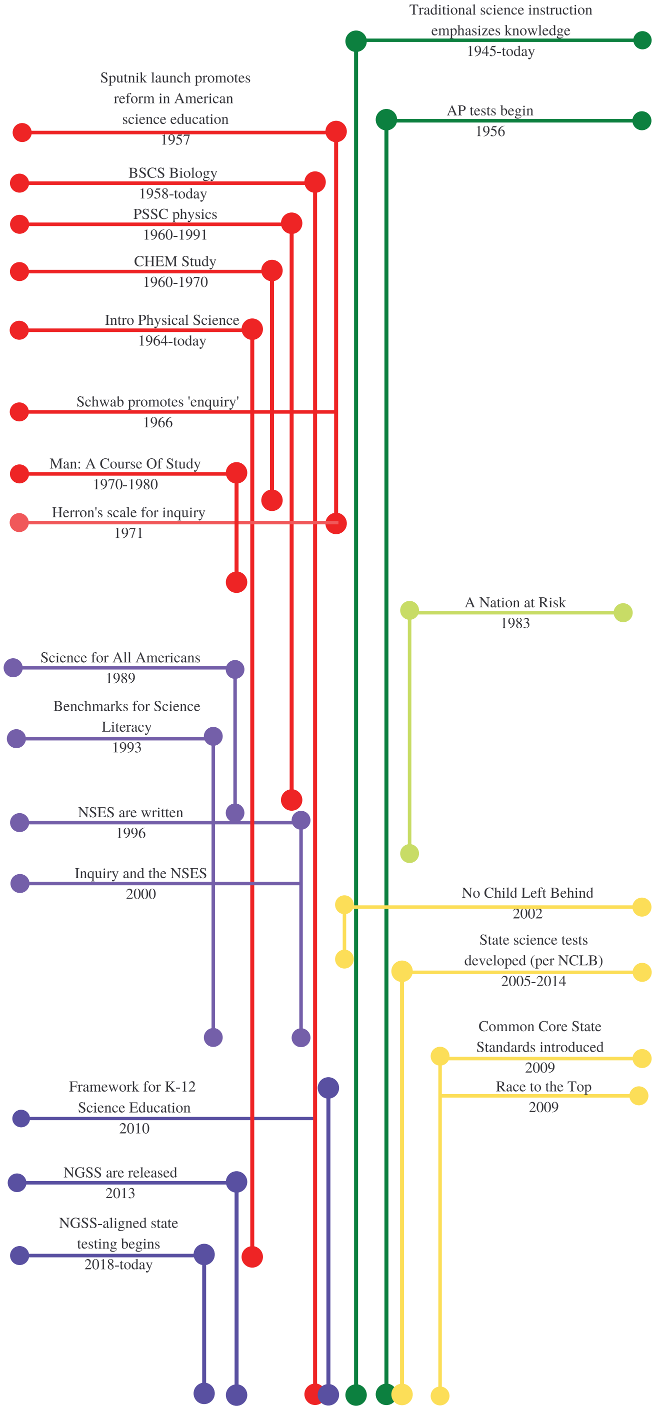
Keywords: NGSS, textbook analysis, inquiry, science education reform

Literature Review

The Historical Direction of Science Education Reform

In order to understand where the NGSS came from, it is first necessary to situate the NGSS within the historical context of education in the United States. Science, like other subjects, was thought to be a place where the development of standards would be useful for guiding instruction. The idea of educational standards aligns with a social efficiency ideology (Schiro, 2012) by endeavoring to make students ready for college and careers. The committees that constructed the *A Framework for K-12 Science Education* and the NGSS consisted of members from both the public and private sectors. The committees included scientists, policy makers, teachers, and business leaders working together with the singular focus of identifying what American students need, in terms of science education, to be college and career-ready (NRC, 2012; NGSS Lead States, 2013).

TIMELINE OF AMERICAN SCIENCE EDUCATION
1945-2021



Science education policy has been largely influenced by international competition since the conclusion of World War II (Yager, 2000). While concerns related to the space race have abated, the position of the United States on international tests of math and science achievement has remained a cause of concern as it has been since the publication of A Nation at Risk in 1983.

While no national standards document existed in American science education during the 1950s or 1960s, the focus of science education was largely driven by the impetus to compete technologically with the Soviets and increase the number of scientists and engineers (Bybee, 1995). The 1960s also saw the rise of inquiry science as a method for approaching laboratory investigations (Schwab, 1962) and laboratory skills were emphasized in most of the post-Sputnik reform curricula, and this group of reform curricula can be found in Figure 1 above.

Project 2061, which commenced in the 1980s, further examined learning in science education. The result of this project produced Science for All Americans which focused on scientific literacy as the goal of science education, rather than the production of scientists (Rutherford & Ahlgren, 1990; Wren, 2014). Science for All Americans was a significant influence on the development of both the Benchmarks for Science Literacy (BSL) and the National Science Education Standards (NSES) (Yager, 2000; Moreno, 1999), further embedding the social efficiency ideology into American science education. The BSL and NSES were the first national science frameworks in the United

States. Though unofficial, the BSL and NSES were instrumental in guiding the development of state-level science education standards and the development of curriculum materials. Science for All Americans also broadened the profile of science, technology, engineering, and mathematics (STEM) education as an interdisciplinary and interdependent field (Wren, 2014).

A note on inquiry. This period, from the introduction of inquiry in the 1960s to today, is marked by a steadily increasing role for the federal government in education policy. The progression of federal education reform from the publication of A Nation at Risk during the Ronald W. Reagan administration, to the passing of No Child Left Behind (NCLB) during the George W. Bush administration, has fully ensconced the ideology of the social efficacy movement into federal education policy (Gardner, 1983; Ravitch, 2010; Ravitch, 2013). NCLB took the core ideology of the social efficacy movement a step farther by requiring both standards and high-stakes assessments in English language arts (ELA), mathematics, and science (No Child Left Behind [NCLB], 2002; Ravitch, 2010; Ravitch, 2013). In contrast to ELA and mathematics, making adequate yearly progress (AYP) toward proficiency on high-stakes assessments was not mandated in science, but progress was still expected (NCLB, 2002; Lontok et al.,2015).

Inquiry's mainstream debut came with the publication of the NSES in 1996. Even though inquiry or enquiry entered the discourse in science education with J. J. Schwab's (1962) publication of *The Teaching of Science as Enquiry*, it took time for these ideas to become widely adopted. Even in 1996, inquiry was largely misunderstood and poorly defined which led to the publication of *Inquiry and the National Science Education Standards* (NRC, 2000) that sought to provide clarity to teachers on the concept of inquiry in the science classroom and guidance on training educators to use inquiry. The term inquiry is used in three different ways in the NSES standards: as abilities students develop, as understandings about what scientists do, and as an approach to teaching and learning.

Though inquiry is not new to science, evidence from research suggests that it is poorly integrated into science instruction (Lebak, 2015; Capps & Crawford, 2013). NCLB has proven to be an obstacle to the integration of inquiry in science instruction because measurement of inquiry skills does not occur on standardized tests (DiBiase & McDonald, 2015). Additionally, authentic engagement in inquiry takes time and resources (Songer et al., 2002; Kraus, 2008). From a pedagogical perspective, this is much like an engineering problem where there are criteria and constraints. Teachers face limits on time, lack access to resources, and they need to cover a significant amount of content. Learning science via inquiry takes time and resources; it is not as expedient as lecturing. Students engaging in authentic inquiry must gather data and often will need to conduct an experiment more than once, as they shift their methodology to account for what they have learned (Morrison, 2014). Since there is no such thing as unlimited time and inexhaustible funding, teachers have had to make pedagogical decisions as to how to teach their classes to meet their goals, which under NCLB have included the pressure to maximize performance on standardized tests. We have tried to represent this history as a timeline in Figure 1.

Function of Textbooks in the Classroom

Textbooks serve a variety of functions in the classroom and often define curriculum (Gamson et al., 2013; Stern & Roseman, 2004). Kesidou and Roseman (2002) point out that

> Curriculum materials are but one of the resources available to teachers, they have a major role in teaching and learning. Many teachers rely on them to provide some or all of their content and pedagogical content knowledge, and this is especially so when the teacher is a novice or is teaching outside his or her area of expertise. (p. 522)

Science education has been a perennial shortage area and this increases the number of teachers who are teaching out of field or with a limited background in their content area (U.S. Department of Education, 2019). This can result in a stronger reliance on the textbook.

Textbooks can be used as a reading assignment where students read either individually or as a group. Questions within a textbook are assigned as either classwork or homework to assess student learning (Davey, 1988). Textbooks can also serve as a planning resource for the teacher (National Research Council, 2000).

Textbook Analyses

For many American teachers, the textbook serves as the curriculum (Gamson et al., 2013; Stern & Roseman, 2004). Therefore, reform to education often includes reform to curricular materials. Textual analysis of these materials is well established as a gauge of the extent of reform (Abd-El-Khalick et al., 2008). In fact, some have called for an increase in the analysis of textual materials (Good, 1993).

Textbook analyses in science education have explored a number of domains. Textbook analysis has been used successfully to examine: nature of science (Abd-El-Khalick et al., 2008; Rodriguez & Niaz, 2004a; Campanile et al., 2015), scientific methodology (Binns & Bell, 2015), history of science (Niaz et al., 2010; Rodriguez & Niaz, 2004a; Brito et al., 2005), use of models (Niaz 1998; Rodriguez & Niaz, 2004b; Justi & Gilbert, 1999), portrayal of scientists (Good et al., 2010; Yacoubian et al., 2017), and the inclusion of inquiry (Herron, 1971; Eltinge & Roberts, 1993, Yang & Liu, 2016). Textbook analyses in science have also been used to examine the use of gendered language (Campo-Englstein & Johnson, 2014; Kahveci, 2010), the use of illustrations (Liu & Khine, 2016; Vinisha & Ramadas, 2013; Slough et al., 2010), and attention to diversity (Powell & Garcia, 1985; Parker et al., 2017).

Methodology

Background Information

In this study, we conducted an analysis of the textbooks in the Interaction

Science Curriculum Project (ISCP). The ISCP project consisted of three textbooks: *Interaction of Man and the Biosphere: Inquiry in Life Science* (Abraham, Beidleman, Moore, Moores, & Utley, 1974), *Interaction of Earth and Time: Inquiry in Earth Science* (Abraham, Chaney, Moores, & Swift, 1976), and *Interaction of Matter and Energy: Inquiry in Physical Science* (Abraham, Balch, Chaney, & Rohrbaugh, 1968). The ISCP was a national curriculum field-tested by more than 100,000 students in the late 1960s and early 1970s. Reviews of *Interaction of Man and the Biosphere* appear in The Quarterly Review of Biology (Brown, 1971) and the American Biology Teacher (Weinberg, 1971). Review of middle school science textbooks have been done before, specifically in relation to Project 2061 (Kesidou & Roseman, 2002) and in general, these reviews found textbooks lacking across a wide range of criteria. However, Kesidou & Roseman did not include the ISCP as part of their 2061 review.

We selected the ISCP texts for three reasons. First, similar to the NGSS, they represent a curriculum that operated on a national scale. Second, they were intended as preparation for some of the better-known reform curricula of the 1960s, like BSCS Biology, the PSSC Physics, CBA Chemistry, and CHEM Study (Weinberg, 1971). Finally, they were not included in the Project 2061 review by Kesidou and Roseman so any information gained from this study would add to the body of knowledge gleaned from textbook analysis. If we can show that the ISCP curricula is compatible with the NGSS, then we will have falsified the claim that the NGSS are a complete revolution in science teaching (Popper, 1959).

ISCP textbooks function "not so much a textbook to be read as a guide to investigation. The passages for reading are short and are interspersed with problem questions and with directions for experiments or investigations" (Weinberg, 1971, p. 244). Unlike many modern textbooks, each book is constructed around a holistic storyline, and meant to be taught as a whole, with each chapter logically flowing into the next. They contain a wide variety of investigations, grade-level appropriate readings, and informative photographs and diagrams. Each also includes several appendices on such concepts as units of measurement, microscope use, and the periodic table.

Interaction of Man and the Biosphere (IMB) opens with the basics of the biosphere and ends with students' responsibility to act as its stewards. It contains 12 content sections, as well as nine appendices on concepts such as units of measurement and microscope use. *Interaction of Earth and Time* (IET) begins by asking questions about the Earth and ends with an exploration of the Earth's place in the universe. Like IMB, IET is made up of 12 sections and three appendices including star charts, star observations, and conversion tables. *Interaction of Matter and Energy* (IME) addresses physical science through both microscopic and macroscopic lenses, and aims to have students investigate both the interactions of individual particles and interactions of macroscopic objects. IME is the longest book of the series in terms of number of sections and page count, consisting of 18 sections and three appendices.

The teacher's edition of each textbook contains supplemental information on inquiry-based teaching methods and facilitating laboratory work. At the time of publication, complete sets of laboratory equipment could be obtained with an order form within the teacher's manual. Unlike modern textbooks that use a wrap-around design for the teacher's edition, these use the same page numbers as the student text, differentiating teacher material with letters after the page numbers. This simple change means that the teacher's editions have the exact pages as the student editions, the font size remains readable, and the supplementary information receives a full-page layout.

Coding Framework

The NGSS are made up of three components: the disciplinary core ideas (DCI), the practices of science and engineering (PSE), and the crosscutting concepts (CCC) (NGSS Lead States, 2013; NRC, 2012). The 42 DCI, which can be viewed as the academic content standards, cover the four domains of life science, physical science, Earth and space science, and engineering design. The PSE form the backbone of how science is to be taught and they provide a framework for how the content should be applied by students. The CCC blur the lines between content areas by tracing key themes from one disciple to another (Krajcik et al., 2014). The three components of the NGSS are combined into performance expectations and are intended to be taught together, seamlessly, with no single component receiving greater emphasis than another (NGSS Lead States, 2013; NRC, 2012; Bybee, 2014; Pruitt, 2015). Teaching the components together is called three-dimensional learning (NGSS Lead States, 2013; NRC, 2012).

We examined each textbook in the three-volume ISCP series, paying careful attention to the student investigations to determine how they aligned with the three dimensions of the NGSS: disciplinary core ideas (DCI), crosscutting concepts (CCC), and practices of science and engineering (PSE). For both the teacher and student version of each book, every ISCP chapter was examined in depth. All readings, activities, and investigations were compared to the three dimensions of the NGSS. In total, 230 individual sections listed in the table of contents from all three texts, including readings, investigations, and 'on your own' activities were analyzed. This represents the entire canon of the series; no sections were omitted. While coding, both authors consulted the relevant sections of the NGSS Standards, NGSS Appendices, and *A Framework for K-12 Science Education* to verify alignment. The NGSS Appendices and *A Framework for K-12 Science Education* were included as reference materials in coding because the present a more granular breakdown of what is in the NGSS Standards document itself.

Coding of relationships to each of the three dimensions was done on a three-point scale representing no alignment, partial alignment, or full alignment. Each of the authors conducted their own independent analyses and coding of each text using the *a priori* coding scheme agreed to before the start of analysis. Both authors have experience working with NGSS and teach in a NGSS-adopting state. Author one, in addition to holding a doctorate in education, has experience teaching NGSS-aligned courses at the high school level, writing NGSS aligned-curricula, and evaluating curriculum materials for implementation. Author two holds a doctorate in science education and has focused a significant amount of his research on reform-based pedagogy.

Following the completion of individual coding, both authors met to discuss discrepancies. Where discrepancies occurred, each author presented their rationale for coding. The authors then consulted the relevant sections of the NGSS Standards, NGSS Appendices, and *A Framework for K-12 Science Education*. All discrepancies were discussed until consensus was reached. The ISCP books represent the body of knowledge available at their publication dates thus DCI coding of lessons and activities was only done when a grade-appropriate performance expectation could be aligned. In a few cases, the NGSS refer to science content that was not known in the 1970s.

Coverage levels correspond to the number of weeks of class time suggested in the teacher's manuals; the greater the number of aligned lessons and investigations, the more class time devoted to that DCI. We decided to categorize heavy coverage as having 11 or more lessons, labs, or activities aligned to a DCI, which would correspond to more than two weeks of instruction. Moderate coverage was categorized as 6 to 10 lessons, labs, or activities, or approximately two weeks of instruction and light coverage was categorized as less than five, or one week of instruction. We believe that this coding scheme corresponds to the experiences of contemporary teachers who plan by the number of weeks devoted to a standard or topic. This coding framework addresses the chapter structure of the texts; chapters primarily have between five and eight subsections on each topic. Individual DCIs are often covered across multiple chapters as content topic grouping differs between the ISCP series and the NGSS.

In contrast, the PSE and CCC are more timeless in nature because they represent general skills and structures that can be applied to a wide variety of circumstances and topics. Students using the ISCP were exposed to CCC and PSE using content that is no longer featured in the standards. For example, when students are learning taxonomy the crosscutting concept of patterns is still emphasized. As such, we opted to count each instance of an aligned investigation, regardless of the presence of a related performance expectation, when coding the PSE and CCC.

Results and Discussion

In keeping with the format of the NGSS, we have elected to present our findings for each text organized according to the PSE, CCC, DCI, and level of inquiry. A brief overview of the contents of each textbook is displayed in Tables 1-3. If all three books were used in sequence across the middle level grades, students would revisit many of the same concepts, such as the energy contained in plants, from multiple scientific perspectives.

Alignment with the Practices of Science and Engineering

A Framework for K-12 Science Education and the NGSS specifically delineate eight practices of science and eight practices of engineering instead of describing all of these collectively as inquiry. It is important to note that there is a significant overlap between the science and engineering practices. Placing the PSE as an equal side of the NGSS triangle underscores the importance of both inquiry and engineering in science pedagogy.

Within the teachers' edition of IMB the authors state "an inquiry approach to the teaching of science is essential if students are to develop initiative and investigative skills" (Abraham et al., 1974, p. xiii). This sentiment is also expressed in the third teacher's editions of IET and IME. The authors further describe the skills needed for inquiry as perception, organization, conceptualization, and application. These are further defined and compared to the PSE in Table 5 below.

The relative alignment of the data from ISCP to the NGSS suggests that many of the characteristics of inquiry

Table 1 *Contents of Interaction of Man and the Biosphere: Inquiry in Life Science*

Section Title	Number of Investigations	Number of Activities
Life in the Biosphere	3	4
Investigating an Interaction	5	1
An Interaction Within an Organism	8	4
Transport Problems	4	4
How Food is Used	2	1
Interacting with the Environment	5	2
Organisms in the Biosphere	3	4
Ecological Interactions	8	4
Mankind in Nature	3	3
Reproduction	1	1
Genetics	6	1
Change Through Time	4	1
Total:	52	30

Table 2 *Contents of Interaction of Earth and Time: Inquiry in Earth Science*

Section Title	Number of Investigations	Number of Activities
Asking Questions	1	1
Gathering Evidence	7	3
Testing Models	2	3
Where You Are	2	2
Describing Things with Numbers	6	1
Some Properties of Water	6	2
The Changing Atmosphere	12	6
Time and Change	3	3
Observing the Landscape I	8	6
Observing the Landscape II	7	4
Seeking Larger Patterns	5	3
Searching the Universe	5	3
Total:	64	37

Table 3 *Contents of Interaction of Matter and Energy: Inquiry in Physical Science*

Section Title	Number of Investigations and Activities
A Way to Begin	1
Structure of Matter: A Model	4
Classification of the Elements: The Structure of Atoms	2
Classification of the Elements: Refining a Model	0
Investigating Properties of Chemical Families	3
Investigating a Compound	6
The Meaning of Measurement	6
Analysis of Motion	9
Motion and Energy	3
Phases of Matter	4
Heat Energy	7
Observing the Behavior of Light	7
Observing the Nature of Waves	4
Energy Conversion	5
Some Chemical Reactions in Living and Nonliving Things	4
Molecules Important for Life	5
Particle Size and Energy	2
Total:	72

have been stable for decades. Within all of the teacher's guides, the authors deemphasize the memorization of facts and advocate for science as way of knowing. This is corroborated by the amount of attention paid by the NGSS authors to previous reform efforts (NRC, 2012).

While predating the NGSS by over 40 years, the exact form of inquiry used in ISCP overlaps considerably with the PSE found in the NGSS. The PSE that occurs most often in IMB are planning and carrying out investigations, analyzing and interpreting data, and using mathematics and computational thinking. In IET, developing and using models as well as using mathematics and computational thinking feature most prevalently. In IME the most prevalent practices are developing and using models, using mathematics and computational thinking, and constructing explanations and designing solutions. In all cases, investigations are frequent, essential to student learning, and correspond to the NGSS focus on phenomena.

Table 4 *Percentage of Investigations and Activities Covering the Practices of Science and Engineering*

Practices of Science and Engineering	IMB	IET	IME
Asking Questions and Defining Problems	0	0.9	0
Developing and Using Models	20.7	27.7	31.9
Planning and Carrying Out Investigations	35.3	12.8	8.3
Analyzing and Interpreting Data	48.7	11.8	23.6
Using Mathematics and Computational Thinking	30.4	40.5	38.8
Constructing Explanations and Designing Solutions	13.4	12.8	54.1
Engaging in Argument from Evidence	14.6	4.9	4.1
Obtaining Evaluating and Communicating Information	9.7	3.9	4.1

IMB: *Interaction of Man and the Biosphere: Inquiry in Life Science*
IET: *Interaction of Earth and Time: Inquiry in Earth Science*
IME: *Interaction of Matter and Energy: Inquiry in Physical Science*

Table 5 *Inquiry Processes of Science in ISCP and the PSES*

Inquiry Processes of Science	NGSS Practices of Science and Engineering
Perception	
Observe carefully	Planning and carrying out investigations
Describe accurately	Analyzing and interpreting data
Measure accurately	
Manipulate lab apparatus	
Setup and use equipment	
Organization	
Identify variables	Planning and carrying out investigations
Compare, classify, and group materials	Analyzing and interpreting data
Conceptualization	
Offer hypotheses	Asking questions and defining problems
Raise questions	Analyzing and interpreting data
Sort and classify data	Developing and using models
Recognize sequences or trends	Constructing explanations and designing solutions
Analyze information	
Make inferences from data	Planning and carrying out investigations
Draw conclusions	
Distinguish between variables	
Determine the effect of variables	
Application	
Apply info to new situations	Planning and carrying out investigations
Investigate	Using mathematics and computational thinking
Design experiments	Engaging in argument from evidence
Predict the effect of variables on experimental results	Obtaining, evaluating, and communicating information
Evaluate hypotheses	

Notably, the practice of students asking questions is not something included in these curricula. Questions are provided to the students for all investigations and students have the opportunity, both explicitly stated and through repeated demonstration, to learn that scientific investigations are always structured around a question, but that question is provided in all but one instance. One difference is that in ISCP, engineering is relatively rare but not wholly absent so student experiences lack significant opportunities to define problems.

The treatment of models within the entire ISCP series is well aligned to the understanding of models as presented in the NGSS. In IET, the authors make it clear that models are useful in explaining observations but that they are not static, instead they change as new observations are made. Further, the authors make it clear that models must be testable and then the students are led through a series of investigations where they not only learn about the Earth-Sun system but also about the process of evaluating models. This process of developing, testing, and revising models is also present in IMB and IME. This treatment of models meets all the criteria within the learning progression for models in grades six through eight as stated in NGSS Appendix F: Science and Engineering Practices.

The practice of planning and carrying out investigations proved challenging to analyze. While students using all three texts would spend significant time in the lab conducting investigations, they are rarely involved in their planning. Thus, the low levels of coverage for this PSE in IME and IET reflect that students are engaged in part of a practice as opposed to a whole practice. Students use more equipment in IME and as a result, there is a greater tension between the planning side of this practice and the carrying-out side. With respect to the criteria specified in the learning progressions in NGSS Appendix F, the ISCP curricula meet all but the first. In the interest of having more investigations, it is clear that the ISCP authors opted to do nearly all of the design work for the students.

In some areas, students conduct their own analysis and interpretation of data that correspond to the highest levels of inquiry (Herron, 1971). This robust level of data analysis and interpretation is not universal and trivial examples also exist in all three texts. Without access to computers, students do not work with large data sets. Charts, tables, and graphs do commonly appear in these textbooks and students are asked to draw conclusions from them. Students are also regularly tasked with making graphs, charts, and diagrams from their own experimental data. Students are routinely asked to connect today's laboratory results with yesterday's models and explanations. In a truly constructivist manner, understanding is built piece by piece and not explicitly provided. Further, the questions at the end of each investigation do not prompt students to share their data but rather promote rigorous analysis. For example, in IET students investigate the heating rates of sand and water. The follow-up questions include:

> Design and carry out an investigation to find out the *cooling* rates of sand and water. How do heating and cooling rates of earth and water affect coastal wind patterns at night? How do heating and cooling rates of earth and water affect oceans and continents during winter? Why do you think fog is forming along this coast [picture provided]? (Abraham et al., 1976, p. 153)

The use of mathematics and computational thinking throughout ISCP includes a strong focus on application of mathematical concepts. As an example, IET investigation 4.1 asks students to make a table with both the latitude of the observer and the altitude of Polaris. Students are then asked how the angles in the second column compare with the angles in the first column. Students then construct an astrolabe and are asked to measure the latitude of their home, construct an average of values obtained by the class, and then to compare that to the latitude given on maps for their location. The type of computational thinking presented throughout the ISCP curriculum diverges from the plug and chug mathematical thinking present in many other texts. As one might expect from a curriculum written in the 1960s and 1970s, use of digital tools is wholly absent.

In keeping with the overall lack of engineering, ISCP students do not design solutions to engineering problems. However, they spend significant time constructing explanations and are often asked to compare their results to a wider, real-world context. Thus, the ISCP curricula meet the criteria specified in Appendix F for the middle-level grade span related to the construction of explanations but not the criteria for designing solutions.

In comparison to other practices, engaging in argument from evidence receives relatively little attention but instances where it does occur are well done and require higher-level thinking. One example of this is a repeated problem presented to students in IME where students are asked on multiple occasions to evaluate two competing theories, a scientific theory and demon theory, based on evidence. In IMB investigation 1.3, students are asked to look at samples that might come from planet X. The analysis questions are: "Were you able to predict which of the unknown materials are alive? Have you proved that some of the unknown materials are *not* alive (Abraham et al., 1975, p.20)?" With these two questions, the authors have gotten to the crux of the difficulties with scientific induction and are asking students in a grade-appropriate way to consider the nature of science and how we know that we know. This is entirely compatible with NGSS Appendix H: Nature of Science and students completing the ISCP curricula would meet all of the criteria specified in the learning progressions in NGSS Appendix F: Science and Engineering Practices.

The treatment of the practice of obtaining, evaluating, and communicating information within ISCP centers on the last two criteria specified in the learning progressions in NGSS Appendix F. Students are expected to:

> Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts. Communicate scientific and/or technical information (eg. About a proposed, object, tool, process, system) in writing and/or through oral presentation. (NGSS Lead States, 2013, Appendix F, p.15)

Outside information is rarely referred to and often something students do on their own when it is used. This may be an issue specific to the time period as access to outside information was more difficult without the internet. Sections for students to read in ISCP are occasionally included within all three texts though it is important to note that these readings are short and provide no extraneous information. However, students are often asked to compare information from their many investigations to information from the book.

Alignment with the Cross-Cutting Concepts

A Framework for K-12 Science Education and the NGSS specifically delineate seven crosscutting concepts that connect all sciences together and help distinguish them from non-science. All of the crosscutting concepts appear within the ISCP curricula. The reader can see that patterns and system models received particular emphasis by the writers of ISCP. To the extent possible, the authors of ISCP wanted students to experience science the way practicing scientists do.

Patterns are the second most prevalent crosscutting concept in the ISCP series, however much of the work done with patterns falls into high school level learning progressions. In all three texts, students are regularly tasked with using patterns to identify cause and effect relationships. In IET, students are asked the exact performance expectation given as the model in NGSS Appendix G: Crosscutting Concepts for patterns. In IME students conduct a series of investigations that collectively identify the characteristics and structure of bluestone, later revealed to be hydrated copper (II) sulfate. Much of the work students do with patterns is based on constructing and revising explanations of phenomena. Improving and reengineering designed systems is not a concern; when engineering tasks are given to students, they are done once.

Cause and effect appears less often and is generally used to predict phenomena in natural and designed systems. While the word correlation is not used, the authors do focus student attention on the strength of their own data. With the exception of genetics, the use of probability is absent. Across all three texts, students construct hypotheses about the nature of cause and effect relationships.

Scale, proportion, and quantity is important throughout the series but is not always the focus of a particular investigation. Particularly strong examples within the series include students' construction and calibration of their own scientific equipment. Calculations are generally qualitative which corresponds to the learning progression specified in NGSS Appendix G for this grade level. Pocket calculators were also a more significant expense at this time and relatively few middle-school students had their own.

Systems and system models is by far the most prevalent crosscutting concept in the ISCP series and meet the criteria laid out in the NGSS for the middle level grade band in full. Models are central to the entire approach of ISCP and are handled at a level of sophistication which is both advanced and rare. Instead of straightforward presentation of a model, students are asked at different times to select between various models or to conduct an extended series of investigations resulting in models that increase in sophistication over time. The role of models in scientific thinking is spelled out for students in all three ISCP texts and students have multiple opportunities to practice refining their own models.

The crosscutting concept of energy and matter may not feature as heavily as some of the other Crosscutting Concepts but it does meet the criteria specified in the middle level learning progression in NGSS Appendix G. While almost all investigations include energy or matter at some level, we chose to only code the investigations where the crosscutting concept was made explicit.

Structure and function as a crosscutting concept appears more in IMB than in the other two texts. Within IMB, structure and function is addressed in terms of organismal morphology, both from a plant and animal perspective, and ecological interactions. An example of the relationship between structure and function in IME has students observe physical waves in a ripple tank and then move to an examination of light passing through small openings, which aligns with the example performance expectation given in NGSS Appendix G.

Stability and change is the least present crosscutting concept across the ISCP curricula. Within IET students, grapple with the changes that have happened and will happen on both local and planetary scales. The most powerful example of stability and change comes at the end of IMB and is a three-page closing entitled "We can't run away any longer (Abraham et al., 1975, p. 328)". Students are urged to consider the effects of a growing human population and finite resources. They are told "We must protect the biosphere, it is the only one we have (Abraham et al., 1975, p. 330)".

Table 6 *Percentage of Investigations and Activities Covering the Crosscutting Concepts*

Crosscutting Concepts	IMB	IET	IME
Patterns	35.3	25	16
Cause and Effect: Mechanism and Explanation	15.8	7	19
Scale, Proportion, and Quantity	7.3	20	18
Systems and System Models	57.3	27	30
Energy and Matter: Flows, Cycles, and Conservation	12.1	5	11
Structure and Function	25	8	12
Stability and Change	11	12	0

IMB: *Interaction of Man and the Biosphere: Inquiry in Life Science*
IET: *Interaction of Earth and Time: Inquiry in Earth Science*
IME: *Interaction of Matter and Energy: Inquiry in Physical Science*

Alignment with the Disciplinary Core Ideas

Although these textbooks were published in the late 1960s and scientific knowledge has continued to advance, much of the material presented aligns with the disciplinary core ideas in the NGSS. Table 7 outlines the coverage of the DCIs within the books. There are also several other examples, not included in the table below, where the books address performance expectations from the elementary or high school grade bands. Further, there is evidence of both cross-disciplinary science learning and emerging engineering design. For example, several instances of Earth and space science DCIs as well as physical science

DCIs can be found in IMB. *In situ*, all are connected with a life science DCI.

All three texts also contain at least one engineering design challenge which aligns to all three engineering design DCIs. The engineering design challenge in IMB tasks students with designing a water purifier. The engineering design challenge in IET tasks students with modifying a telescope. The engineering design challenge in IME tasks students with constructing and calibrating a thermometer.

Table 7 *Disciplinary Core Idea Alignment*

Disciplinary Core Ideas	IMB	IET	IME
LS1.A: Structure and Function	Heavy	–	–
LS1.B: Growth and Development of Organism	Light	–	–
LS1.C: Organization for Matter & Energy Flow in Organisms	Heavy	–	–
LS1.D: Information Processing	Medium	–	–
LS2.A: Interdependent Relationships in Ecosystems	Medium	–	–
LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	Light	–	–
LS2.C: Ecosystem Dynamics, Functioning, and Resilience	Light	–	–
LS2.D: Social Interactions and Group Behavior	–	–	–
LS3.A: Inheritance of Traits	Medium	–	–
LS3.B: Variation of Traits	Heavy	–	–
LS4.A: Evidence of Common Ancestry and Diversity	Light	Medium	–
LS4.B: Natural Selection	Light	–	–
LS4.C: Adaptation	Light	–	–
LS4.D: Biodiversity and Humans*	–	Medium	–
ESS1.A: The Universe and Its Stars	–	Heavy	–
ESS1.B: Earth and the Solar System	–	Heavy	–
ESS1.C: The History of Planet Earth	–	Medium	–
ESS2.A: Earth Materials and Systems	–	–	–
ESS2.B: Plate Tectonics and Large-Scale System Interactions	–	Light	–
ESS2.C: The Roles of Water in Earth's Surface Processes	–	Light	–
ESS2.D: Weather and Climate	–	–	–
ESS2.E: Biogeology*	–	Light	–
ESS3.A: Natural Resources	Light	–	–
ESS3.B: Natural Hazards	–	Light	–
ESS3.C: Human Impacts on Earth Systems	Medium	–	–
ESS3.D: Global Climate Change	Light	–	–
PS1.A: Structure and Properties of Matter	–	–	Heavy
PS1.B: Chemical Reactions	–	–	Heavy
PS1.C: Nuclear Processes*	–	–	–
PS2.A: Forces and Motion	–	–	Light
PS2.B: Types of Interactions	–	–	Light
PS2.C: Stability and Instability in Physical Systems	–	–	–
PS3.A: Definitions of Energy	–	–	Light
PS3.B: Conservation of Energy and Energy Transfer	–	–	Light
PS3.C: Relationship Between Energy and Forces	–	–	–
PS3.D: Energy in Chemical Processes and Everyday Life	–	–	Light
PS4.A: Wave Properties	–	–	Medium
PS4.B: Electromagnetic Radiation	–	–	Medium
PS4.C: Information Technologies and Instrumentation	–	–	–
ETS1.A: Defining and Delimiting an Engineering Problem	Light	Light	Light
ETS1.B: Developing Possible Solutions	Light	Light	Light
ETS1.C: Optimizing the Design Solution	Light	Light	Light

IMB: *Interaction of Man and the Biosphere: Inquiry in Life Science*
IET: *Interaction of Earth and Time: Inquiry in Earth Science*
IME: *Interaction of Matter and Energy: Inquiry in Physical Science*

Conclusions and Implications

This study sought to find evidence of NGSS-aligned practices in older curricula to support or refute the assertion that the NGSS are an evolution of previous work (NRC, 2012; NGSS Lead States, 2013). We chose to focus on one curriculum in detail because, as Popper (1959) points out, it requires only one counter-example to disprove a general rule. Given that so many elements of the NGSS are clearly evident in the ISCP series, the argument that the NGSS are an evolution not a revolution is supported. Elements of all three aspects of NGSS-aligned instruction (PSE, DCI, and CCC) are clearly present in this curriculum which predates the NGSS by 40 years. The teaching of curriculum history as linear is clearly problematic (see Figure 1). As the timeline makes clear, the revolutionary nature of the NGSS largely depends on the comparison one is making. If one compares the Next Generation Science Standards to the preceding emphasis on test scores promoted by NCLB and the Common Core State Standards, then the NGSS appear to be a large shift. However, a longer historical perspective shows that this is a return to reform-oriented science education, and the NGSS have a great deal in common with the earlier National Science Education Standards, the Benchmarks for Science Literacy, and are largely a continuation of the science education reforms of the post-Sputnik era.

Interestingly, many of the investigations in the ISCP series include the presence of what the *A Framework for K-12 Science Education* and the NGSS term three-dimensional instruction. "When they [students] explore particular disciplinary core ideas from dimension 3, students will do so by engaging in practices articulated in dimension 1, and should be helped to make connections to the crosscutting concepts in dimension 2" (NRC, 2012, p. 30). That is, lab investigations in this curriculum frequently link science practices with a crosscutting concept and a disciplinary core idea. Krajick (2015) points out that while lab activities have been used historically, their purpose was not directly related to student learning of content. What makes the lab activities in this curriculum unique is that they are not an addition to content, they are the means by which students access, make sense of, and learn content. This method of instruction, which exemplifies the constructivist methods praised in *A Framework for K-12 Science Education*, can be seen in a curriculum that predated the Framework and the NGSS by more than 40 years.

When science teachers teach evolution, they focus on both evidence of common ancestry and the appearance of new traits. While we have shown that that there is significant evidence of NGSS-aligned structures and practices in the ISCP, there are also differences that highlight how the NGSS are different from prior practice. These differences fall into three domains: changes in the body of scientific knowledge, changes in curricular progression and prioritization, and the emphasized focus on engineering within science education.

Changes to scientific knowledge include the obvious example of DNA, which is not included in the ISCP curricula but is now considered central to the work of biologists and features heavily in modern science education. Likewise, the language and understanding of climate change has evolved a great deal. ISCP ends with a consideration of human population growth, which comes from an older perspective of conserving resources.

The NGSS also present changes in curricular progression and prioritization. In some cases, content topics have moved from one grade band to another. For example, in life science the standards relating to learning about cellular organelles moved from the domain of high school biology to middle school life science. Additionally, what content is deemed of value to include in the curriculum has also shifted. Climate change and sustainability now feature heavily in the NGSS as these are pressing issues where scientific literacy is critical to both solving future problems and developing well-informed voters.

Other examples include shifts in priority; engineering is lightly touched upon in the ICSP curricula where it is now a major focus of the Next Generation Science Standards. This represents a major change to the practice of science teachers and to the professional education that prospective science teachers receive. This also represents an important shift from what was once referred to as Industrial Arts or 'shop class' and has now become technology education. Science and technology education are now more linked than ever with considerable overlap between the two; in the 1970s they were far more distinct.

Many of the arguments about the revolutionary nature of the NGSS made by prominent figures have been made in K-12 practitioner journals (Pruitt, 2015; Yager, 2015; Krajick 2015). This discussion is also mirrored in practitioner journals for science teacher educators (Bybee, 2014; Pruitt, 2014). This discourse may be a cause of an unwarranted sense of alarm for teachers who, in most cases, were not consulted in their state's decision to adopt or adapt the NGSS and who may not be familiar with the history of science education reform (Shapiro, 2018). The evidence provided by this single example indicates that the history of science education reform is more complicated than commonly portrayed (see figure 1). Oversimplification of the history of science education reform has gotten to the point where it is now distorting our past. While an immediate comparison between the NGSS and previous science education requirements may seem like a large change, we need to recognize that the methods of science significantly predate the NGSS and that curricula based on scientific methods retain a great deal of value.

It is important, especially as teachers continue the work of realigning their curricula and curriculum developers continue producing materials aligned to the NGSS, to remember that we have had strong inquiry-based curricula in the past. In the acknowledgements in IET the authors note that they owe an enormous debt of gratitude to nearly 1,500 teachers and more than 100,000 students who participated in field testing this series. While field-testing is time-consuming and difficult, it may be necessary. A recent analysis of NGSS alignment completed by EdReports.org on six middle school curricula produced by major publishing companies to meet the NGSS showed significant deficiencies (Sawchuk, 2019). Examination of the ISCP model lessons and units, which contain key features of the NGSS, may help teachers in their work. In addition to the increase in efficiency, using work that may be familiar to teachers may reduce anxiety (Haag & Megowan, 2015). Previous efforts at reform-based science education represent a treasure trove of models and ideas that could be examined for potential use today.

References

Abd-El-Khalick, F., Waters, M., & Le, A. (2008). Representations of Nature of Science in High School Chemistry Textbooks over the Past Four Decades. *Journal of Research in Science Teaching, 45*(7), 835-855.

Abraham, N., Beidleman, B., Moore, J., Moores, M., & Utley, W. (1974). *Interaction of man and the biosphere: Inquiry in life science*. Chicago: Rand McNalley & Company.

Abraham, N., Chaney, D., Moores, M. & Swift, R. (1976). *Interaction of earth & time: Inquiry in earth science.* Chicago: Rand McNalley & Company.

Abraham, N., Balch, P., Chaney, D., & Rohrbaugh, L. (1968). *Interaction of matter and energy: Inquiry in physical science.* Chicago: Rand McNalley & Company.

Binns, I., & Bell, C. (2015). Representation of Scientific Methodology in Secondary Science Textbooks. *Science & Education, 24*(7), 913-936.

Brito, A., Rodriguez, M., & Niaz, M. (2005). A Reconstruction of Development of the Periodic Table Based on History and Philosophy of Science and

Its Implications for General Chemistry Textbooks. *Journal of Research in Science Teaching,42*(1), 84-111.

Brown, R. (1971). Review of Interaction of man and the biosphere: Inquiry in life science. *The Quarterly Review of Biology, 46*(1), 69-70.

Bybee, R. W. (1995). Science curriculum reform in the United States. *Redesigning the science curriculum*, 12-20.

Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of science teacher education*, *25*(2), 211-221.

Campanile, M., Lederman, N., & Kampourakis, N. (2015). Mendelian Genetics as a Platform for Teaching About Nature of Science and Scientific Inquiry: The Value of Textbooks. *Science & Education, 24*(1), 205-225.

Campo-Engelstein, L., & Johnson, N. (2014). Revisiting "The fertilization fairytale:" an analysis of gendered language used to describe fertilization in science textbooks from middle school to medical school. *Cultural Studies of Science Education, 9*(1), 201-220.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening?. *Journal of Science Teacher Education*, *24*(3), 497-526.

Davey, B. (1988). How Do Classroom Teachers Use Their Textbooks? *Journal of Reading, 31*(4), 340-345.

DiBiase, W., & McDonald, J. R. (2015). Science teacher attitudes toward inquiry-based teaching and learning. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *88*(2), 29-38.

EdReports.org. (2017-2019). *Reports Center/Science*. https://www.edreports.org/reports/?s=science

Eltinge, E., & Roberts, C. (1993). Linguistic content analysis: A method to measure science as inquiry in textbooks. *Journal of Research in Science Teaching, 30*(1), 65-83.

Fulmer, G., Tanas, J., & Weiss, K. (2018). The challenges of alignment for the Next Generation Science Standards. *Journal of Research in Science Teaching, 55*(7), 1076-1100.

Gamson, D., Lu, X., & Eckert, S. (2013). Challenging the Research Base of the Common Core State Standards: A Historical Reanalysis of Text Complexity. *Educational Researcher, 42*(7), 381-391.

Gardner, D. P. (1983). *A Nation at Risk: The Imperative for Educational Reform. An Open Letter to the American People. A Report to the Nation and the Secretary of Education.* Washington D. C.: Department of Education.

Good, J., Woodzicka, J., & Wingfield, L. (2010). The Effects of Gender Stereotypic and Counter-Stereotypic Textbook Images on Science Performance. *The Journal of Social Psychology, 150*(2), 132-147.

Good, R. (1993). Science Textbook Analysis. *Journal Of Research In Science Teaching, 30*(7), 619.

Haag, S., & Megowan, C. (2015). Next generation science standards: A national mixed-methods study on teacher readiness. *School Science and Mathematics*, *115*(8), 416-426

Herron, M. (1971). The nature of scientific inquiry, *The School Review,* 79 (2), 171-212.

Justi, R., & Gilbert, J. (1999). A Cause of Ahistorical Science Teaching: Use of Hybrid Models. *Science Education, 83*(2), 163-77.

Kahveci, A. (2010). Quantitative Analysis of Science and Chemistry Textbooks for Indicators of Reform: A complementary perspective. *International Journal of Science Education, 32*(11), 1495-1519.

Kesidou, S., & Roseman, J. (2002). How well do middle school science programs measure up? Findings from Project 2061's curriculum review. *Journal of Research in Science Teaching, 39*(6), 522-549.

Krajcik, J. (2015). Three-dimensional instruction. *The Science Teacher*, *82*(8), 50.

Krajcik, J., Codere, S., Dahsah, C., Bayer, R., & Mun, K. (2014). Planning instruction to meet the intent of the Next Generation Science Standards. Journal of Science Teacher Education, 25(2), 157-175.

Kraus, R. (2008). *Overcoming the difficulties of inquiry-based learning through the use of coaching.* [Doctoral dissertation, Illinois Institute of Technology].

Kuhn, T. (1967). *The structure of scientific revolutions.* Chicago: The University of Chicago Press.

Lebak, K. (2015). Unpacking the complex relationship between beliefs, practice, and change related to inquiry-based instruction of one science teacher. *Journal of Science Teacher Education*, *26*(8), 695-713.

Liu, Y., & Khine, M. (2016). Content Analysis of the Diagrammatic Representations of Primary Science Textbooks. *EURASIA Journal of Mathematics, Science & Technology Education, 12*(8), 1937-1951.

Lontok, K. S., Zhang, H., & Dougherty, M. J. (2015). Assessing the genetics content in the Next Generation Science Standards. *PloS one*, *10*(7), e0132742

Metts, S. (2013). Notes from the field editor. *The Science Teacher. 80*(3), 6

Moreno, N. P. (1999). K-12 science education reform–a primer for scientists. *Bioscience*, *49*(7), 569.

Morrison, J. A. (2014). Scientists' participation in teacher professional development: The impact on fourth to eighth grade teachers' understanding and implementation of inquiry science. *International Journal of Science and Mathematics Education*, *12*(4), 793-816.

National Research Council & Division of Behavioral Social Sciences Education. (2000). *Science Teaching Reconsidered: A Handbook*. National Academies Press.

National Research Council. (2012) *A framework for K-12 science education: practices, crosscutting concepts, and core ideas.* Washington: The National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. National Academies Press.

Niaz, M. (1998). From cathode rays to alpha particles to quantum of action: A rational reconstruction of structure of the atom and its implications for chemistry textbooks. *Science Education, 82*(5), 527-552.

Niaz, M., Klassen, S., McMillan, B., & Metz, D. (2010). Reconstruction of the history of the photoelectric effect and its implications for general physics textbooks. *Science Education, 94*(5), 903-931.

No Child Left Behind Act of 2001, P.L. 107-110, 20 U.S.C. § 6319 (2002).

NSTA. (2013). *Program: National conference on science education.* National Science Teachers Assocation.

NSTA. (2014). *Program: National conference on science education.* National Science Teachers Assocation.

NSTA. (2015). *Program: National conference on science education.* National Science Teachers Assocation.

Parker, R., Larkin, T., & Cockburn, J. (2017). A visual analysis of gender bias in contemporary anatomy textbooks. *Social Science & Medicine, 180*, 106.

Popper, K. (1959). *The logic of scientific discovery*. New York: Harper & Row.

Powell, R., & Garcia, J. (1985). The portrayal of minorities and women in selected elementary science series. *Journal of Research in Science Teaching, 22*(6), 519-533.

Pruitt, S. L. (2015). The Next Generation Science Standards: Where are we now and what have we learned?. *Science & Children*, *52*(9), 7-9.

Ravitch, D. (2010). *The death and life of the great American school system: How testing and choice are undermining education*. New York, NY: Basic Books

Ravitch, D. (2013). *Reign of error: The hoax of the privatization movement and the danger to America's public schools*. Vintage.

Rodriguez, M., & Niaz, M. (2004a). A Reconstruction of Structure of the Atom and Its Implications for General Physics Textbooks: A History and Philosophy of Science Perspective. *Journal of Science Education and Technology, 13*(3), 409-424.

Rodriguez, M., & Niaz, M. (2004b). The Oil Drop Experiment: An Illustration of Scientific Research Methodology and its Implications for Physics Textbooks. *Instructional Science: An International Journal of Learning and Cognition, 32*(5), 357-386.

Rutherford, F., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Sawchuk, S. (2019, February 28). Science curriculum reviews are out, and results aren't great [Blog post]. Retrieved from http://blogs.edweek.org/edweek/curriculum/2019/02/edreports_science_series_first_reviews.html

Schiro, M. (2012). *Curriculum theory: Conflicting visions and enduring concerns*. Sage.

Schwab, J. (1962). *The teaching of science: The teaching of science as enquiry.* Cambridge, MA: Harvard University Press.

Shapiro, L. (2018). *High school science teachers' receptivity to the Next Generation Science Standards: An examination of discipline specific factors* (Publication no. AAT 10751507.) [Doctoral dissertation, Northeastern University]. ProQuest Dissertations Publishing.

Slough, S., Mctigue, E., Kim, S., & Jennings, S. (2010). Science Textbooks' Use of Graphical Representation: A Descriptive Analysis of Four Sixth Grade Science Texts. *Reading Psychology, 31*(3), 301-325.

Songer, N. B., Lee, H. S., & Kam, R. (2002). Technology-rich inquiry science in urban classrooms: What are the barriers to inquiry pedagogy?. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *39*(2), 128-150.

Stern, L., & Roseman, J. (2004). Can middle-school science textbooks help students learn important ideas? Findings from project 2061's curriculum evaluation study: Life science. *Journal of Research in Science Teaching, 41*(6), 538-568.

U.S. Department of Education. (2019). Teacher shortage areas. Retrieved from https://tsa.ed.gov/#/home/.

Vinisha, K., & Ramadas, J. (2013). Visual Representations of the Water Cycle in Science Textbooks. *Contemporary Education Dialogue, 10*(1), 7-36.

Weinberg, S. (1971). Review of Interaction of man and the biosphere: Inquiry in life science. *The American Biology Teacher. 33*(4), 243-244.

Wren, K. (2014). Before the Common Core, there was science for all Americans the landmark AAAS book continues to influence education reform 25 years after it defined the concept of science literacy. *Science, 345*(6200), 1012-1013.

Yacoubian, H., Al-Khatib, A., & Mardirossian, L. (2017). Analysis of the Image of Scientists Portrayed in the Lebanese National Science Textbooks. *Science & Education, 26*(5), 513-528.

Yager, R. (2000). The history and future of science education reform. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 74*(1), 51.

Yager, R. E. (2015). Biology education in an era of acronyms. *The American Biology Teacher*, *77*(8), 563-564

Yang, W., & Liu, E. (2016). Development and validation of an instrument for evaluating inquiry-based tasks in science textbooks. *International Journal of Science Education,38*(18), 2688-2711.

Author's Contact Information
Lesley J. Shapiro, Ed.D.
Classical High School
770 Westminster Street
Providence, RI 02903
shapiro.l@northeastern.edu

Rudolf V. Kraus, Ph.D.
Rhode Island College
600 Mount Pleasant Avenue
Providence, RI 02908
rkraus@ric.edu