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The Changing Scenery of K-12 Science: From Committee of Ten to Frameworks

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Abstract: Over the past 120 years, K-12 science has had numerous changing emphases from preparing future scientists to science for all (scientific literacy). A historical analysis of these changes illustrates these pendulum swings that have influenced K-12 science. These changes have put stress on all aspects of K-12 including teachers of science, administrators, pre-service preparation, curriculum developers, professional development activities, and state-federal policy makers. Today, the *Framework for Science Education* (2012) organizes content by learning progressions and incorporates engineering design into K-12 curriculum.

Key words: science curriculum, scientific literacy, policy analysis

1. Introduction

At the start of the second decade of the 21st century, K-12 science is once again undergoing revision. Over the past 120 years, the focus of science instruction has changed drastically numerous times. To put these changes in perspective, we must examine previous K-12 science curriculum patterns. The goals of K-12 science education have had fluctuations from an emphasis on preparing future scientists/engineers to science for all (scientific literacy). These drastic fluctuations have made it difficult for teachers of science, especially at the elementary level; administrators; curriculum developers; textbook publishers; pre-service preparation programs; and policymakers. Today these changes are continuing at the national professional organizations and the federal government levels. Historical perspective presented below will help build an understanding of these pendulum swing changes.

2. Committee of Ten

The National Educational Association in 1893 published a report that provided guidance to K-12 schools. The Committee was responsible for coordinating entrance requirements for college admission and identifying content to be studied at the pre-college level. This Committee was composed of ten college presidents and principals of secondary schools. Charles Eliot, President of Harvard, chaired the committee. There were nine different subject committees, including three for science (natural history; physics, chemistry, and astronomy; and geography, geology, and meteorology). Prior to 1890, the study of science was considered a new subject in the school curriculum. It was believed that science would help develop the observational and inductive abilities of

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students. One of the major recommendations of the final report was that 25% of the total school curriculum was to be devoted to the study of science. The Committee of Ten had described science as a disciplinary study that would develop a person's mental capabilities. Laboratory work was considered a major role of science courses to be conducted at the high school level. For example, the physics curriculum identified specific laboratory experiences that all high school students should complete prior to admission to college. DeBoer (1991) summarized the operation and result of the Committee of Ten report (1893).

In 1896, the National Education Association formed a committee to design ways of implementing the Committee of Ten report. This entitled Committee on College Entrance Requirements submitted its final report in 1899. The courses recommended by this Committee became the norm for high school graduation and college entrance. The Committee recommended that students study English for two years, languages other than English for four years, mathematics for two years, history for one year, and science for one year. In addition, students would have six electives offered in their high school program resulting in a total of 16 units. Of the 16, a minimum of one was to be science. As a result, all students in high school whether they were planning to attend college or not would take the same subjects.

3. Progressive Era

During the years of the Progressive Era (1917–1957), the focus of school science changed. This time frame is known as child-centered education where real world applications became more important, social value for knowledge, and school was to be enjoyable and meaningful to the student. This orientation clashed with the Committee of Ten recommendations. During this period, the developed sequence of high school science courses of general science, biology, chemistry, and physics became established; and discussions involved whether the emphasis of science should be on the application or developmental versus the knowledge of subject matter. Dewey wrote about the scientific method for developing general problem-solving skills. In his address to the 1910 American Association for the Advancement of Science conference, Dewey stressed the six components of the scientific method. Subsequently, Dewey (1938) revised his model of the scientific method to include only four steps. Today, we have textbooks where some use a four step model and others a five-step model. As a result, students are now uncertain about how to design scientific investigations.

In 1927, Craig, for his doctoral dissertation at Columbia University, designed the elementary science curriculum for the city of St. Louis schools. This became the standard for many textbooks to follow. These textbooks would be classified as "reading about science" to form generalizations (Hurd, 1970). According to Bybee and DeBoer (1994), Craig's model still exists with elementary science textbooks.

3.1 Impact of the Launching of Sputnik I on K-12 Science Education

On October 4, 1957, the Soviet Union launched Sputnik I into orbit. This 83.6 kg polished aluminum sphere had a diameter of 58 cm with 4 antennas that circled the Earth every 92 minutes with the velocity of 8000 m/s (Ubell, 1957). The American people were frightened and bewildered by this orbiting metal sphere. This launch shook America's confidence in their technological superiority and caused government officials, politicians, scientist, and educators to scramble to catch up. In order for the United States to catch up, schools had to improve their science curriculum from the social aspects of the progressive era to more rigorous study. Congress passed the National Defense Education Act in 1958 to promote the development of high quality mathematics and science programs that would facilitate students enrolling in these courses.

The President's Scientific Research Board recognized the importance of quality of K-12 science education. In addition, the serious shortage of well-qualified secondary teachers mathematics and sciences, especially in the area of physical science, was noted. The American Association for the Advancement of Science (AAAS, 1957) called for specialized training for K-12 teachers of science. Communism of the Soviet Union was perceived as a threat for several reasons: (1) it was a different governing system than democracy, (2) communist countries had the atomic or hydrogen bomb, and (3) United States of America had never lost a technology race (Wissehr, Concannon & Barrow, 2011). A sense of urgency to improve mathematics and science education became a common theme in an effort to prevent communism from spreading (Hein, 2006).

Government funding for curriculum development and professional development was forthcoming through the National Science Foundation (Trowbridge & Bybee, 1996). This "golden age of science education" saw an extensive process beginning with summer writing conferences (by a combination of scientists and master science teachers). Teachers field tested the new developed curriculum in their classrooms the following year. They would then revise the curriculum as necessary over a 2–3 year time. These government developed curricula for physics, chemistry, biology and other science courses had extensive field testing before being turned over to commercial companies for production and distribution. Laboratory investigations were an integral part of the curriculum and frequently had separate manuals. Examples of these reformed curricula for secondary schools included *Biological Science Curriculum Study* (BSCS), *Physical Science Curriculum Study* (PSCS), *ChemStudy*, *Earth Science Curriculum Project* (ESCP) and *Harvard Project Physics* (HPP) at the secondary level. At the elementary level, reforming curriculum included *Science—A Process Approach* (SAPA), *Elementary Science Study* (ESS) and *Science Curriculum Improvement Study* (SCIS). Of all these programs, only BSCS is still active today.

In addition to developing reformed curriculum, the National Science Foundation and other funding sources provided summer programs for teachers of science to help them implement the new curriculum. Typically, mornings were spent on content development with afternoons focusing on laboratories. Professional development was national in scope and administered at the regional level (DeBoer, 1991). These professional development experiences were beneficial to science teachers by increasing their content knowledge and providing them with credit and advanced degrees. In addition, schools needed equipment to implement the new curriculum, and grants from the government helped supply these funds. Regarding the assessment, programs established a set of objectives, stated in behavioral terms, about what students would do to demonstrate their mastery. However, Atkins and Black (2003) noted some teachers felt pressured to give up spontaneous learning opportunities in favor of addressing specific learning objectives. Wissehr, Concannon and Barrow (2011) provides a historical perspective examining the social, political and educational climate in the United States leading up to the launch of Sputnik I.

3.2 A Nation at Risk and Other Reports

After the success of the United States' space program, there was concern that the science curriculum and opportunities were no longer important. This Back to Basics movement emphasized reading and mathematics. Part of this backlash movement was because parents were uncomfortable with aspects of "new math" and the content emphasis of high school science. In 1974, the National Science Foundation stopped funding for developing of innovative curriculum and professional development. This Congressional action was in reaction to the anthropology curriculum (*Man: A Course of Study*) which was developed with National Science Foundation funding.

In 1981, Harms and Yager compiled three major National Science Foundation sponsored projects —a review of 1955–1975 science education research literature (Hegelson, Blosser & Howe, 1977), case studies by Stake and Easily (1978), and the 1977 National Survey of K-12 Personnel (Weiss, 1978). This document was entitled Project Synthesis and was used to develop a discrepancy model for science education. They identified four different goal clusters: personal needs, societal issues, academic preparation and career education and awareness. The greatest emphasis (95%) was on the academic preparation.

In 1983, a small report, *A Nation at Risk,* was released in April. This report had been commissioned by the U.S Department of Education and was thought to be recommending the disbanding of the newly formed Department of Education. However, the focus of the report was upon the curriculum needs for high school graduates. Local schools could compare their graduation requirements with neighboring schools. At its release, it was a time of little national news; therefore, the report became the major news of the week. Regarding high school science, the *Nation at Risk* report recommended increasing the minimum number of courses from one to two. It did not identify which two courses should be included for graduation.

4. Science Policy Documents

Two documents in the last decade of the twentieth century provided guidance for states and local schools as they prepared K-12 science curriculum. First, long-term effort by the AAAS to reform K-12 science identified what all students should know and be able to do when they graduate at the end of 12th grade. The title of the project was Project 2061 document — *Science for All Americans (SFAA* Rutherford & Ahlgren, 1989*)*, thereby, providing a broad view of defining science literacy. *Benchmarks for Scientific Literacy* (AAAS, 1993) organized the *SFAA* topics into grade level groupings: K-2, 3-4, 5-8, and 9-12. Two volumes of the *Atlas of Scientific Literacy* (AAAS, 2001, 2007) have a series of stand maps that illustrates the concepts of the *Benchmarks*.

Second, the *National Science Education Standards* (NSES; National Research Council [NRC], 1996) considered inquiry as the overarching goal for scientific literacy. The *NSES* identifies what science students are to know, how teachers are to teach, and how teachers are to assess students. The *NSES* expanded beyond the content of *SFAA* with sections on professional development, teaching, assessment, system, and program standards. Bybee (1997) stressed that K-12 teachers of science should not teach processes of science separate from the content. The combining of science processes with scientific knowledge, reasoning and critical thinking allows students to develop a richer deeper understanding of science content. This orientation was counter to the process of science emphasis of the post-Sputnik curriculum.

K-12 teachers of science had difficulty implementing inquiry as recommended by *NSES* especially veteran teachers. Therefore, NRC published *Inquiry and the National Science Education Standards* (2000) which identified five essential features of inquiry regardless of grade level:

(1) Scientifically oriented questions that will engage students;

(2) Evidence collected by students that allows them to develop and evaluate their explanations to the scientifically oriented questions;

(3) Explanations developed by students from their evidence to address the scientifically oriented questions;

(4) Evaluation of their explanations, which can include alternate explanations that reflects scientific understanding; and

(5) Communication and justification of their proposed explanations.

These five attributes are on a continuum from teacher-directed at one end to student-centered at the other end. Therefore, a K-12 teacher of science can rate their teaching approach, curriculum and assessment for level of inquiry. The degree of the teacher-student centeredness can vary for each attribute. Barrow (2006) provides a summary over the past century of how science education has provided multiple interpretations of inquiry. However, K-12 teachers of science, students, and parents are still confused about what is inquiry. Inquiry must engage students in scientifically oriented questions that are of interest to the students; otherwise they will not establish ownership. *NSES* (1996) did not recommend inquiry be used for every science topic. In using an inquiry orientation, students will require a longer learning time because they bring to each investigation their current explanations and abilities including "prior knowledge". Bransford, Brown, and Cocking (1999) found that a deeper understanding of science concepts occur for students when prior knowledge is taken into consideration when planning instruction.

4.1 Physics First Movement

Leon Lederman, Nobel winning physicist, started to question the sequence of high school science curriculum, (Korsunsky & Agar, 2008). Since the Committee of Ten report (1983), high school physics had been considered the most abstract and last course in the high school sequence. Physics instruction emphasized the mathematical applications of knowledge. It also had a problem of low enrollment, college preparation emphasis, and young girls were not provided with examples that they can relate to their lives. Physics First movement is recommending that physics become the ninth grade science course for all students. In addition, the focus should be upon concepts rather than mathematical applications. In schools that have implemented the Physics First approach, the next two recommended courses would be chemistry and biology in that order. High school biology curriculum has changed drastically since the Committee of Ten's focus and has become more biochemical in orientation. When students have background information in physics and chemistry concepts, they are able to build a better understanding of biology for the 21st century.

Physics First orientation has resulted in a need for professional development for teachers of science. This professional development must address both types of physics teachers. For traditional physics teachers, they must become comfortable with teaching from a conceptual approach. For noncertified physics teachers, they must become comfortable with the content and teaching approaches for all students. Frequently, the modeling method (Jackson, Dukerich & Hestes, 2008) is recommended for all types of physics instruction.

4.2 No Child Left Behind and Other Assessments

The impact of No Child Left Behind (NCLB, 2002) has been drastic upon K-12 science. At the elementary level, reduced instruction time resulted in the elimination of the teaching of science. Consequently, middle school students frequently lack basic foundations of science. The emphasis upon mathematics and literacy and their assessment has caused teachers and administrators, additional stress. The goal of NCLB ideal was that all students would be able to perform satisfactorily in the year 2014. However, the benchmark that was to be used was for all students to be performing on grade level. Grade level is a norm referenced score; therefore, half of the students will be above the mean and half below the mean. Consequently, this goal is impossible. The state assessments that were developed were highly variable; and it has made it impossible to do valid comparisons. Today, discussion is occurring upon what is going to happen with modification of the targets of NCLB.

State tests have been used to document student performance for a long period of time. For example, the New York State Regency exams have been used for graduation for over 100 years. Some states require some level of performance for promotion and graduation. These high-stakes tests create stress for teachers, administrators, parents, and students. For other states, it is only the teachers and administrators that feel stress of students not reaching certain level of performance on NCLB. Generally, these tests will include multiple-choice items covering the content of the discipline, constructed responses, and performance events. The last two categories require extensive resources for scoring. According to the NCLB, all students (grades 3–8) will annually complete mathematics and literacy tests. Currently, science is to be tested once in grades 3–5, 6–8, and high school. This results in a grade range test rather than grade level emphasis. Recently, several states decided to address the high school requirement through an end of course examination for a particular science course like biology. Budget limitations are causing states to go only to a multiple-choice orientation.

The Obama administration has forged common state standards and their programs entitled Blueprint for Educational Reform with a new goal that all 2020 high school graduates should be ready for college and careers. They are encouraging courses which would include: four years of English (college preparation level), four years of science (including two laboratory-based courses), four years of mathematics (students will be prepared for college-level algebra), and four years of social science (e.g., history and economics). High school graduates should have more analytical skills than traditional fact emphasis that high school courses have provided. It is unclear how this will influence end of course assessments. This initiative will continue the emphasis on under-represented students and core initiatives. It is desired that high school students will be considered first in the world in the number of bachelor’s degrees awarded.

Traditionally, assessment was defined as either summative (state tests, unit test, etc.) or formative. Formative assessment allows the teacher to identify learning problems of individual students during instruction. Keeley, Eberle, and Dorcey (2008) have developed a series of formative probes for a variety of science concepts. These probes allow teachers to analyze for concepts, use of terminology, transfer of learning, prior knowledge, level of sophistication, reasoning and ability to write or verbalize and explanation. Teachers will be able to determine individual students’ ideas and categorize them as having scientific accuracy, preconceptions, conceptual misunderstanding (misconceptions), and nonscientific beliefs. A probe would be administered at the start of the unit on the probe, students would identify an aspect from a scenario and explain/identify the best explanation. Analyzing student responses will help teachers of science be able to organize their instruction most effectively.

5. Framework for Science Education

In 2010, the NRC released for comments a draft version for the K-12 content science framework. This document focuses only upon the revision of the content aspects of *NSES* (1996). This framework is organized in a grouping of grades (K-2, 3–5, 6–8, and 9–12). They attempted to reduce the number of science topics, but to explore each in a greater depth through ongoing learning progressions. Students will build upon their previous understandings of biology, physical science (chemistry and physics), Earth and space science, and engineering and technology. Each of these areas is to contribute 25% of the K-12 science to be studied. The inclusion of engineering and technology will cause considerable stress for the traditional high school structure. For example, there is currently a lack of textbooks with this focus and an extensive need for professional development for incorporating this new area into teachers’ knowledge base to become comfortable for teaching this area. The areas (biology, chemistry and physics, earth and space, and engineering and technology) to be emphasized are: the four discipline areas, cross-cutting of the discipline areas (big ideas of science), and “practices of science and engineering design". The report chose to replace the word "inquiry", because of confusion of its meaning, with "practices". Their use of "practices" is similar to the processes of science emphasis of the post-Sputnik. But "practices" are not to be done in isolation. Bybee (2011) provides an in depth overview of how inquiry has evolved from processes of science of the Sputnik era to inquiry to practices. Bybee shows how practices are appropriate for both science and engineering problems.

There are several principles that are guiding the Framework document (2012). They include: children's capacity to learn science (they're born investigators), understanding by students develops over time, both knowledge and "practices" must be considered, and the importance of engineering and technology are necessary in developing understanding and using scientific knowledge and "practices". Learning progressions described how students successfully learn more sophisticated ways of thinking about these science and engineering concepts over multiple years. In designing of learning progressions, it begins with what most students know about the concepts and their reasoning ability when they enter school. At the other end, what they are expected to understand about the topic when they complete high school. Research-based conceptual studies helped the NRC in identifying different aspects for particular concepts.

Learning progressions are new to teachers of science at all levels, administrators, textbook developers, teacher preparation programs, etc. The general format in the progression would have K-2 focus upon ideas about phenomena that students can investigate and directly experience. While in grades 3–5, some aspects will involve things where children develop a macroscopic orientation to a phenomena. For grades 6–8, the atomic level explanations of physical phenomena and cellular explanations would be the focus without the detail of inner workings. At the high school level, the emphasis would be explanations that are subatomic and subcellular.

The NRC collected extensive reviewer comments about the draft. National Science Teachers Association (NSTA) and other organizations hosted sessions for reaction. According to blogs, many high school teachers are very uncomfortable about the changing structure of course offerings being proposed. Many schools still have the sequence proposed by the Committee of Ten (1893). Others have adopted the Physics First approach. Both of these models are incompatible with the framework document. School districts that do not have extensive curriculum supervision will not be familiar with learning progressions and how things need to happen at their grade levels.

The development of the new science content standards was written including K-12 teachers of science. These new science standards are to have high school graduates either college or career ready. This *Next Generation Science Standards* (*NGSS*, Achieve, 2013) has been voluntarily adopted by 26 states. After draft standards are written, they were critiqued by stakeholders at least twice. Some issues identified by Pruitt (2011) addressed by the writing committee are: grade band vs. grade levels, high school courses , subject or integrated content at middle level, and exemplary features reported in international reports. After the NGSS are finalized, a common science assessment will be developed by Achieve. *NGSS* will be different from the Common Core that was developed for mathematics and literacy because of voluntary state participation. It is projected that future NSTA professional development conferences will highlight ways to implement NGSS. This scenery will require the K-12 science community, pre-service programs, state policy makers, and textbook publishers to work together as they implement NGSS. Multiple orientations will be needed to prepare K-12 teachers, veteran secondary science teachers, and administrators to become familiar with *NGSS*. Pratt (2013) provides suggestions for helping K-12 teachers of science become familiar with *NGSS*. Also, pre-service programs with content courses and methods faculty must provide fundamental background for all four content areas. Methods faculty must utilize practices rather than inquiry in their courses.

6. Summary

The Committee of Ten's recommendation that 25% of the high school curriculum was to be science that was to prepare individuals for college. Subsequently, the National Education Association Committee established 16 units as criteria for high school graduation, but only mandated one science course. The launch of Sputnik by the Soviet Union in 1957 resulted in an emphasis on preparation of future scientist; replacing the Progressive Era's emphasis on science for all. Numerous reports and policy documents have impacted K-12 over the past two decades of the twentieth century. The "Back to Basic" movement and NCLB resulted in reduced time, especially at elementary level, for science instruction.

The new Framework for Science (NRC, 2012) and *NGSS* (Achieve, 2013) drastically changes the curriculum for K-12 science. This new emphasis on technology and engineering design will result in another scenery change. This drastic change will impact professional development programs, curriculum developers, textbook publishers, and teacher preparation programs, etc. It will impact existing K-12 teachers of science and future teachers and administrators. Or will K-12 schools take an emphasis of waiting till this new focus falls out of favor and continue their existing curriculum? Regardless, teachers of science need to be aware of the previous K-12 science changes.

There are numerous questions that will need to be addressed in this changing scenery of science education. How do we deal with situations when teachers do not teach what is necessary in the earlier levels? What about students who do not develop understanding of the discipline; therefore, have difficulty in the cross-cutting integration? How do teachers of science become comfortable with "practices"?

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