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Research Article

NGSS and the Landscape of Engineering in K-12 State Science Standards

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Abstract: Recent documents pertaining to K-12 education have fostered a connection between engineering and science education to help better prepare our students and future citizens to better meet the current and future challenges of our modern and technological society. With that connection, there has been a concerted effort to raise the visibility of engineering within K-12 science education, which is reflected in the *Framework for K-12 Science Education* and the recently released *Next Generation Science Standards*. As states look towards the adoption and implementation of the *Next Generation Science Standards,* it is important to take a deeper look at the shift in K-12 science education that is being suggested by these documents and what that means in terms of the potential changes for states that have chosen to adopt these standards. The main research question that has guided the work for this paper is: What is the extent and quality of the engineering that is present in state science standards and the *Next Generation Science Standards*? This paper will present a detailed analysis of the landscape of engineering in K-12 policy before and after the release of the NGSS through a comparative case study of academic state science standards and *Next Generation Science Standards*. This comparison provides insight into what the widespread adoption of the NGSS would mean in terms of potential changes in the way we implement science education in the United States. © 2015 Wiley Periodicals, Inc. J Res Sci Teach 52:296–318, 2015.
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NGSS and the Landscape of Engineering in K-12 State Science Standards

The *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013), based on the *Framework for K-12 Science Education* (National Research Council [NRC], 2012a), represent a shift in the way we view science education. One major shift is the endorsement for increasing the visibility and understanding of engineering by "raising engineering design to the same level as scientific inquiry in science classroom instruction at all levels, and by emphasizing the core ideas of engineering design and technology applications" (NGSS Lead States, 2013, Executive Summary, p. 1). The NGSS are new K-12 science standards, developed through a collaboration of states, that "are rich in content and practice and arranged in a coherent manner across disciplines

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and grades to provide all students an internationally benchmarked science education" (Executive Summary, p. 1). As of the end of 2013, eight states and the District of Columbia have adopted the standards, along with several other states making significant progress towards adoption (Workosky, 2014). Although the NGSS are not federally mandated standards, they are poised to play a significant role in state educational policy, just as the *National Science Education Standards* (NRC, 1996) did before.

Integrating engineering into the K-12 classroom is gaining national and international attention. Recent national documents pertaining to K-12 education have fostered a connection between engineering and science education to help better prepare our students and our society to meet the current and future challenges of our modern and technological society (NRC, 2007; 2009; 2012a). Additionally, it is essential for all citizens to see this connection between science and engineering in order to make more informed decisions in their everyday lives, and strengthening this connection will help the U.S. to remain competitive in the global economy in which we live (NRC, 2012a). Internationally, we are seeing calls for integrated STEM classrooms, curricula, and standards, which highlight the need for engineering, coming to the forefront (Organisation for Economic Co-operation and Development [OECD], 2008; Rennie, Venville, & Wallace, 2012). This increasing emphasis on including engineering in education standards and other policy documents is a first step toward affecting change in classroom practice.

However, even with the increasing attention, there are barriers to the integration of engineering in the K-12 system. For some, integrating engineering into K-12 science education represents more content that needs to be taught (Coffey & Alberts, 2013). Others argue that the addition of engineering to K-12 could add another silo and "perpetuate the politics and territorial disputes among the science, technology, engineering, and mathematics disciplines" (Bybee, 2010; p. 11). Even with the articulation of high-quality standards, schools and teachers generally must develop their own structures for integration, as there are not many resources (Roehrig, Moore, Wang, & Park, 2012). Furthermore, the engineering education community has had little of the political power needed to push its agenda forward (Bybee, 2010).

Given the attention the NGSS is receiving, an important question that we should be asking is just how much change the NGSS represents in comparison with current policies among U.S. States? To help answer this, our research specifically compares the engineering within the NGSS to recent state science standards documents. Our purpose is to begin to characterize the shifts within U.S. science education policy by reporting an analysis of the engineering within the recent state science standards as well as in the NGSS. We utilize the *Framework for a Quality K-12 Engineering Education* (Moore et al., 2014), a broad definition of engineering at the K-12 level, as the means for assessing the extent and quality of the current state of K-12 engineering education. This work was guided by the following research questions:

- What is the extent and quality of the engineering that is present in state science standards and the Next Generation Science Standards?
- What are the potential changes to the landscape of engineering in K-12 science education resulting from the increased emphasis placed on engineering in the *Framework for K-12 Science Education* and the Next Generation Science Standards?

To assess the *extent* of engineering within a standards document, we considered whether engineering was explicitly integrated or included in the standards, the frequency with which elements of the *Framework for Quality K-12 Engineering Education* appeared in the standards, and the distribution of those elements across grade bands. The *quality* of the engineering within the standards was assessed by considering how comprehensively the documents as a whole addressed the elements of the *Framework for a Quality K-12 Engineering Education*. These terms are presented in more depth in the Research Design section.

Literature Review

When looking at the increased emphasis that is being placed on engineering in the NGSS, it is important to highlight some of the main arguments behind why the addition of engineering into K-12 classrooms is beneficial to student learning. Three main arguments in favor of this are that: (1) engineering thinking helps with the development of 21st century skills in students, (2) engineering pedagogies have potential to increase student achievement in mathematics and science, and (3) engineering contexts have potential to increase student interest in STEM disciplines and careers. The following paragraphs provide detail for these arguments.

Engineering practice, at its core, is a way of thinking in order to solve problems for a purpose. This way of thinking is useful beyond engineering as a career; it can help with the development of 21st century skills; i.e., the skills necessary to be successful in the 21st century (NRC, 2012b). Engineering thinking is comprised of engineering design processes and engineering habits of mind, which include systems thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations (NRC, 2009). One argument for the integration of engineering into the science curriculum comes from the need to better prepare students for complex, interdisciplinary problems and to provide more authentic and real-world meaning in the classroom (NRC, 2012a). According to Brophy, Klein, Portsmore, and Rogers (2008), engineering education can support the acquisition of a wide range of important knowledge and skills for literate citizens that are associated with comprehending and using STEM knowledge in order to solve real-world problems.

The inclusion of engineering in K-12 classrooms can also lead to improved learning and achievement in science and mathematics (Brophy et al., 2008; Carlson & Sullivan, 2004), increased technological literacy, improvements in school attendance and retention, and a better understanding of what engineers do, all of which can lead to increased numbers of students who pursue careers in engineering (NRC, 2009). Engineering activities can be intrinsically motivating by tapping into a child's natural curiosity about how things work and by deepening the teaching and learning for students in K-12 environments across multiple areas of STEM content and process (Brophy et al., 2008). Furthermore, Olds, Harrell, and Valente (2006) found an increase in students' understanding of simple machines after implementing an engineering design activity into a middle school science class. At the high school level, Apedoe, Reynolds, Ellefson, and Schunn (2008) found an increase in students' understanding of atomic interactions and energy after implementing an engineering design activity in a high school chemistry class. Additionally, it has been argued that the inclusion of engineering in K-12 classrooms provides a real-world context for learning mathematics and science, problem-solving opportunities, teamwork development and communication skills, and it provides a fun and hands-on setting that will improve students' attitude toward STEM careers (Hirsch, Carpinelli, Kimmel, Rockland, & Bloom, 2007; Koszalka, Wu, & Davidson, 2007).

Further benefits of introducing engineering into the K-12 curricula are increased interest in STEM subjects and careers in STEM fields. Many recent policy documents have made the argument that the U.S. economy needs more engineering and STEM professionals, especially from underrepresented populations, if we are to remain competitive. For example, the executive report to the President of the United States entitled *Prepare and Inspire: K-12 Education in Science Technology, Engineering, and Mathematics (STEM) for America's Future*, states that the U.S. must prepare students with a strong STEM background in order to be competitive in a global society (President's Council of Advisors on Science and Technology, 2010). *Rising Above the Gathering Storm* (NRC, 2007) also noted that economic growth, as well as national security, is inexorably tied to our ability to train and retain professionals in STEM fields. Furthermore, the entire focus of the report *Changing the Conversation* (NRC, 2008) is about attracting and retaining diverse thinkers and populations (particularly women and underrepresented minorities) into STEM fields by getting the public to understand engineering. The need for multiple pathways that allow students to move through K-12 STEM education into STEM fields and careers has also been widely identified as critical to the future of America's global competitiveness (Rivoli & Ralston, 2009). Several studies found an increase in students' interest in these areas after implementing engineering into K-12 science and mathematics classes (Apedoe et al., 2008; Cantrell, Pekcan, Itani, & Velasquez-Bryant, 2006; Nugent, Kunz, Rilett, & Jones, 2010; Olds et al., 2006). There was also an increase found in students' interest and attitudes in STEM subjects in studies that involved curriculum used as extra curricular programs such as Adventure Engineering (Mooney & Laubach, 2002), Engineering is Elementary (Cunningham, 2008), and In the Middle of Engineering (Rivoli & Ralston, 2009).

So if we take the above arguments to be convincing, we are lead to wonder: If engineering is important for students to learn in K-12, is it necessary to add them to the standards? And, if so, how should they be added?

Academic Standards and K-12 Engineering Education

Academic standards are benchmarks for the concepts and skills to which students are expected to have mastered by the end of their education. When looking at the role of academic standards in the United States' K-12 educational system, it is important to note that while academic standards have received increasing attention at the state and national level in recent years, they are not new. Academic standards have played a role in the educational system since the Committee of Ten set out to standardize high school education more than a century ago through recommendations that advocated that education should prepare all students to be successful in life. These recommendations led to the elementary-secondary structure of education still present in the U.S. today (DeBoer, 1991; NRC, 2010). The purpose of educational standards and standards-based reform is to "establish clear, coherent, and challenging content as learning outcomes for K-12 education" (Bybee, 2010; p. 58). Standards-based reform became more prevalent in the 1980s and 1990s (e.g., Project 2061; American Association for the Advancement of Science [AAAS], 1993) with the development of the *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 1989), and *Science for All Americans* (AAAS, 1990). These important works, among others, set the stage for U.S. states to develop and adopt educational standards in science and mathematics. Furthermore, continued reform has brought about the development of the *Common Core State Standards* (CCSS; National Governors Association Center for Best Practices [NGA], & Council of Chief State School Officers, 2010) and the *Next Generation Science Standards* (NGSS Lead States, 2013). The overwhelming state adoption of the CCSS – Mathematics and English Language Arts (NGA, 2010), as well as the rapidly increasing number of states that are adopting the NGSS, indicates that the idea of standards-based reform is appealing to policy makers.

Several NRC reports have taken up the issue of whether or not engineering in K-12 should be represented in academic standards. With the general consensus that engineering standards are needed for K-12 (NRC, 2010; see also NRC, 2009; 2012a; 2014), there are a number of questions about whether the standards should be stand-alone entities or integrated into other disciplines. The report *Standards for K–12 Engineering Education?* (NRC, 2010) suggested embedding the necessary and relevant learning goals of engineering into the standards of other STEM disciplines, which would draw attention to the existing STEM connections by mapping the big ideas from engineering onto the current standards in these other disciplines. Lewis (2007) agrees that the development of engineering standards is necessary and beneficial for learning at all ages, and one possible approach is to integrate engineering into science content standards. Other researchers in engineering education have also advocated for the addition of engineering concepts into mathematics, science, and technology courses as a way to infuse more engineering into K-12 classrooms without stand-alone standards (Cantrell et al., 2006; English, 2008; Gattie & Wicklein, 2007). Several states, such as Massachusetts, Minnesota, and Oregon, have followed this idea of integrating engineering into existing standards by including explicit engineering learning outcomes within their recent academic science standards (Massachusetts Department of Education, 2006; Minnesota Department of Education, 2009; Oregon Department of Education, 2009). More recently, the *Framework for K-12 Science Education* (NRC, 2012a) addressed this issue by highlighting the importance of the integration of science, engineering, and technology, and including a call for a set of science standards that include engineering. This call has been partially realized through the publication of the *Next Generation Science Standards* (NGSS), a common set of science education academic standards created in conjunction with 26 lead states across the U.S., all states have the option to adopt these as their own if they so choose. However, the NGSS purposefully only integrates engineering through engineering design stating, "It is important to point out that the NGSS do not put forward a full set of standards for engineering education, but rather include only practices and ideas about *engineering design* [emphasis added] that are considered necessary for literate citizens" (NGSS Lead States, 2013, Appendix I, p. 3).

Aspects of Engineering Needed for Literate Citizenry

With the overall conclusion that engineering should be integrated into the standards of other disciplines, it is important to determine the content of the relevant and necessary learning goals in engineering that K-12 students should be learning in order to develop engineering literate citizens. This idea of developing engineering literacy is included in the *Framework for K-12 Science Education* as part of their argument for literate citizens:

> Science, engineering, and technology permeate nearly every facet of modern life, and they also hold the key to meeting many of humanity's most pressing current and future challenges. Yet, too few U.S. workers have strong backgrounds in these fields, and many people lack even fundamental knowledge of them. (NRC, 2012a, p. 1)

This claim echoes that of other recent national documents, which call for improvements in K-12 science and mathematics education in order to remain competitive in the global economy of the 21st century (NRC, 2007; 2009; 2010; 2011; 2014). Conclusions from *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* (NRC, 2009) stated that K-12 engineering education should emphasize engineering design; incorporate developmentally appropriate mathematics, science, and technology skills; and promote engineering habits of mind (NRC, 2009). Additionally, this report makes claims that the aspects of engineering design processes which should be highlighted include that engineering design is: (1) highly iterative; (2) open-ended in that a problem may have many possible solutions; (3) a meaningful context for learning scientific, mathematical, and technological concepts; and (4) a stimulus to systems thinking, modeling, and analysis. The engineering "habits of mind" refer to the values, attitudes, and thinking skills associated with engineering, and these include: (1) systems thinking; (2) creativity; (3) optimism; (4) collaboration; (5) communication; and (6) attention to ethical considerations (NRC, 2009). But engineering literacy is a nebulous idea. Historically, scientific literacy has been the goal of reform in science education (e.g., AAAS, 1990; 1993; Bybee, 1997; DeBoer, 2000). However, according to DeBoer (2000), scientific literacy usually implies "a broad and functional understanding of science for general education purposes and not preparation for specific scientific and technical careers" (p. 594). He further argues that these ideas of scientific literacy come from too many perspectives. These issues are parallel to the kinds of issues revolving around engineering literacy.

Differing perspectives will inherently point to different outcomes of what a K-12 engineering education should be. Even before the release of the NGSS, several states chose to include engineering education at the K-12 level. Carr, Bennett, and Strobel (2012) found that 41 states included engineering in their academic standards documents; 12 of which included engineering within their science standards. Through their assessment of all states' standards (all subjects) for the inclusion of engineering, they found that the "big ideas" of what constituted "doing engineering" were reasonably comprehensive. The big ideas they identified included the nature of engineering well beyond engineering design. Yet, NGSS (NGSS Lead States, 2013) includes only engineering design. Arguments in favor of this limitation include that engineering design is the distinguishing mark of engineering (Dym, 1999) and that engineering design is the engineering equivalent to scientific inquiry (NRC, 1996). The other side argues that this is not a reasonable estimation of how engineers work or think (de Figueiredo, 2008; Trevelyan, 2010). Just like scientific inquiry is not seen as everything one should know about the nature of science (Lederman, 2006; McComas, 1998; see also Koehler, Bloom, & Binns, 2013), engineering design does not represent everything one should know about the nature of engineering (Moore et al., 2014; NRC, 2009).

As Penuel and Fishman (2012) point out, previous attempts to enact change through standards have fallen short. According to these authors, one of several reasons for this is the lack of a consistent interpretation of the standards, and a first step toward a consistent interpretation is a clear picture of the current landscape. As science teachers and science teacher educators start to make sense of the NGSS and what these standards mean for the teaching and learning of science, it is important to take a deeper look into the engineering aspects of these standards that have the potential to be adopted by all states. While the NGSS is not intended to put forward a comprehensive set of engineering standards (NGSS Lead States, 2013), the standards are making a commitment to integrate engineering into the structure of science education. As we look towards the implementation of these new science standards, we are left with a number of questions related to the increased emphasis on engineering. What are these standards asking students and teachers to do in regards to engineering? As teacher educators, how do we best prepare current and future science teachers to integrate engineering into their science instruction? One of the first steps should be to assess the different aspects of engineering that are present in state adopted standards, including the NGSS, in order to provide a comprehensive inventory of what these documents are suggesting that K-12 students should know and be able to do with regards to engineering. Using the *Framework for a Quality K-12 Engineering Education* (Moore et al., 2014) as an evaluation tool, this research study presents a thorough look into the engineering that is represented in these documents to provide detailed information to help science teachers and science teacher educators make sense of integrating engineering in science education.

Research Design

The qualitative research design employed in this study was an embedded, multiple comparative case study (Yin, 2009) approach, in which multiple units of analysis helped to illustrate the past and current landscape of engineering in K-12 science. This case study involved two main cases: (1) status of engineering present in state academic science standards prior to the release of NGSS and (2) status of engineering present in the NGSS. Each state served as an embedded case with the opportunity to compare across the different states, or embedded cases, before and after the NGSS adoption. To evaluate the landscape of engineering prior to the release of the NGSS, the science standards documents from each of the 50 states were compiled and analyzed using document content analysis as suggested by Krippendorff (2013). The NGSS document was also analyzed using this method. Content analysis is often used to analyze large quantities of text (Weber, 1990) such as standards documents. This research method uses a systematic approach to make valid and replicable inferences from the text (Krippendorff, 2013). The background and experiences of individual coders are an important part of content analysis since their own interpretations of texts form the basis for their analysis and the coders should be identified to ensure replicability of research findings (Krippendorff, 2013). The research team that participated in the content analysis consisted of one professor of STEM education, with emphasis in engineering and mathematics, and four graduate researchers. There were two graduate researchers from mathematics education and two from science education—one of the science education researchers also had a master's degree in engineering. Additionally, each member of the research team had K-12 teaching experience.

Another important consideration when conducting a large content analysis that requires the work of multiple researchers is to formulate clear directions for coders to ensure the replicability and reliability of the coding between researchers (Krippendorff, 2013). With the recent emergence of engineering at the K-12 level, there did not exist a comprehensive set of criteria that could be used to assist with the development of coding categories and descriptions used to evaluate the amount and quality of engineering at this level. Therefore, prior to the content analysis, the research team developed *The Framework for Quality K-12 Engineering Education (Framework for QEE),* which included 12 key indicators that were used to guide the coding and categorization of the current state science standards documents. Many national documents (e.g., NRC, 2009; 2010), including the *Framework for K-12 Science Education* (NRC, 2012a) and the NGSS (NGSS Lead States, 2013), provide a structure for the consideration of engineering in K-12. Each of these documents recognizes that the definition presented falls short of a complete definition of engineering. This was the impetus for the development of the *Framework for QEE* described in detail in Moore et al. (2014) and used as the research lens in this work.

The Framework for Quality K-12 Engineering Education

The *Framework for QEE* was developed through a research design study (Hjalmarson & Lesh, 2008), which was initially based off of learning outcomes for undergraduate accreditation requirements (ABET, 2014) and then modified through five iterations to more appropriately represent a K-12 setting. Expert engineering and engineering education feedback and content analysis, curriculum, and teacher implementation studies were also used as part of the feedback loops for the iterations. Multiple researchers completed these preliminary coding iterations in order to reach consensus on the development of the meaning and description of each of the key indicators. This was important for the replicability and reliability of the content analysis to ensure that the *Framework for QEE* indicators had a similar meaning across researchers because the coding of the state science standards occurred in pairs. A final truncated version of the *Framework for a Quality K-12 Engineering Education* is presented in Figure 1. The research on the development process of this *Framework for QEE* as well as the full version can be found in Moore et al. (2014). Throughout this article, the acronyms for each indicator will be used (as defined in Figure 1).

Data Collection and Analysis

To analyze the landscape prior to the release of the NGSS, the state standards documents for science as of December 2011 were identified from state departments of education websites and compiled into a working database. The final version of the NGSS was also added to the database upon its release in April 2013. Each of the standards documents and the NGSS were treated as a

<table>
<tr><th colspan="2">Key Indicator</th><th>Description</th></tr>
<tr><td colspan="2">Complete Processes of Design (POD)</td><td>Design processes are at the center of engineering practice. Solving engineering problems is an iterative process involving preparing, planning and evaluating the solution. Students should understand design by participating in each of the sub-indicators (POD-PB, POD-PI, POD-TE) below.</td></tr>
<tr><td rowspan="3">Sub-indicators of POD</td><td>Problem and Background (POD – PB)</td><td>Identification or formulation of engineering problems and research and learning activities necessary to gain background knowledge.</td></tr>
<tr><td>Plan and Implement (POD – PI)</td><td>Brainstorming, developing multiple solutions, judging the relative importance of constraints and the creation of a prototype, model or other product.</td></tr>
<tr><td>Test and Evaluate (POD – TE)</td><td>Generating testable hypotheses and designing experiments to gather data that should be used to evaluate the prototype or solution, and to use this feedback in redesign.</td></tr>
<tr><td colspan="2">Apply Science, Engineering, Mathematics Knowledge (SEM)</td><td>The practice of engineering requires the application of science, mathematics, and engineering knowledge and engineering education at the K-12 level should emphasize this interdisciplinary nature.</td></tr>
<tr><td colspan="2">Engineering Thinking (EThink)</td><td>Students should be independent and reflective thinkers capable of seeking out new knowledge and learning from failure when problems arise.</td></tr>
<tr><td colspan="2">Conceptions of Engineers and Engineering (CEE)</td><td>K-12 students not only need to participate in an engineering process, but understand what an engineer does.</td></tr>
<tr><td colspan="2">Engineering Tools, Techniques, and Processes (ETool)</td><td>Students studying engineering need to become familiar and proficient in the processes, techniques, skills, and tools engineers use in their work.</td></tr>
<tr><td colspan="2">Issues, Solutions, and Impacts (ISI)</td><td>To solve complex and multidisciplinary problems, students need to be able to understand the impact of their solutions on current issues and vice versa.</td></tr>
<tr><td colspan="2">Ethics (Ethics)</td><td>Students should consider ethical situations inherent in the practice of engineering.</td></tr>
<tr><td colspan="2">Teamwork (Team)</td><td>In K-12 engineering education, it is important to develop students' abilities to participate as a contributing team member.</td></tr>
<tr><td colspan="2">Communication Related to Engineering (Comm-Engr)</td><td>Communication is the ability of a student to effectively take in information and to relay understandings to others in an engineering context.</td></tr>
</table>

Figure 1. Truncated version of the *Framework for a Quality K-12 Engineering Education.*

single text. The unit of coding, or the smallest element that was analyzed, in each of these texts was the statement or concept that students should know or understand (Krippendorf, 2013). We acknowledge that, for each of the state standards documents, the organization and specific terminology used to describe the concepts that are to be learned and understood by K-12 students varies, but for the sake of consistency we will refer to the units of coding as *standards,* regardless of the language used within the documents.

The NGSS are organized by two main categories: Performance Expectations (PEs) and Learning Goals (LGs) within the Foundation Boxes, which are designed to connect the PEs to the Science and Engineering Practices, the Disciplinary Core Ideas, and the Crosscutting Concepts identified in the *Framework for K-12 Science Education*. We used the PEs, which are "the policy equivalent of what most states have used as their standards" (NGSS Lead States, 2013, Executive summary, p.2) and the LG statements, which "ensure curriculum and assessment developers should not be required to guess the intent of the performance expectations" (NGSS Lead States, 2013, Executive summary, p.2), as the units for coding in the NGSS.

The research team used the *Framework for a Quality K-12 Engineering Education* during the content analysis of the standards documents as a rubric for identifying evidence of the key indicators in each of the standards documents. To ensure that our coding reflected how standards directly addressed engineering, it was decided that a standard should only be coded if the standard was met within an engineering context. A standard was determined to have an engineering context if the students were considered to be *doing engineering* or *learning about engineering*. Students are considered to be *doing engineering* when they are engaged in complete or partial processes of design or activities that involve students in engineering thinking and habits of mind. Students are considered to be *learning about engineering* when they are studying design processes, conceptions of engineers and engineering, and closely related skills and topics. Any instance of engineering context within a state science standard document was entered into a master spreadsheet along with the standard and grade level, and two members of the research team then coded this standard individually. Each key indicator was treated separately, thus a standard could potentially be coded with multiple indicators. Before we began final coding, we tested the consistency of our coding with the *Framework for QEE* by having all researchers code an individual state, first in sections then as a whole to calibrate our understandings of the key indicators developed for the *Framework for QEE.*

Once the key indicators for the *Framework for QEE* were set, each of the standards documents were assigned two raters from our research team. After completing the coding of a document individually, the two raters compared codes for agreement. Krippendorf's Alpha (α; Krippendorf, 2013) was used to measure inter-rater reliability for the coding of both the state standards documents and for the NGSS document. Inter-rater reliability for the coding of the recent state standards documents was $\alpha = 0.81$ and for the NGSS document was $\alpha = 0.90$, which are reliable levels of agreement (Krippendorf, 2013). Additionally, to resolve any discrepancies between raters' codes, all researchers discussed the codes, and all disagreements were resolved via discussion and consensus. Only after consensus was reached was the data aggregated and analyzed. All data reported here represent the final coding reached through this consensus process.

Following the individual coding of the state science standard documents and the NGSS, the codes were grouped and evaluated according to different outcomes within the data (Yin, 2009) to help guide the assessment of engineering found within academic science standards. The extent and quality of engineering within the standards are defined by the following three outcomes: the type and extent of engineering present, the distribution of engineering across the grade bands, and the comprehensiveness of engineering within the science standards.

The first outcome was used to assess the type and extent of the engineering present within the science standards documents and the NGSS. With science standards being created at the state level, states have the choice whether to include engineering in their science standards, and therefore during the analysis of each standards document, individual states were classified for their inclusion of engineering according to the levels of *explicit*, *implicit*, or *none*. A state was classified as having *explicit* engineering in their science standards if their science documents included strand titles, headings, or categories that mentioned the words, "engineering", "designed world", or "technological design." *Implicit* engineering was assigned to those states where the previous words were not mentioned in headings, but there was clear evidence of elements of engineering. The last level of engineering was no engineering, which indicated that the standards documents did not have evidence of engineering in their science standards documents. The NGSS were classified as being explicit due to the integration of specific PEs with engineering.

The second outcome was to look at the distribution of engineering across the grade bands in K-12. The grade bands were selected according to the specific grade bands identified in the

Framework for K-12 Science Education (NRC, 2012a) and the NGSS (NGSS Lead States, 2013), and included the following: K-2, 3–5, 6–8, and 9–12.

As a third and final outcome used to provide a detailed picture of the landscape of engineering, we assessed the comprehensiveness of engineering within the science standards prior to and after the release of the NGSS. For a set of science standards to be identified as providing a comprehensive engineering education, the document needed to satisfy four criteria. First, the documents needed to fit the above definition for explicit engineering. Second, the three most central aspects of engineering (Processes of Design [POD], Applications of Science, Engineering, and Mathematics [SEM], and Engineering Thinking [EThink]) must be included in all four grade bands and must be addressed multiple times. These indicators were determined to be central to K-12 engineering education based on recommendations from the NRC report, titled *Engineering in K-12 Education: Understanding the Status and Improving the Prospects,* which concludes that the three general principles for K-12 engineering education should emphasize engineering design, incorporate developmentally appropriate mathematics, and science knowledge and skills, and should promote engineering habits of mind (NRC, 2009). Third, the key indicators, Conceptions of Engineers and Engineering (CEE), and Engineering Tools and Processes (ETool), which are important to the development of students' understanding of the profession of engineering, should be present multiple times in at least two of the grade bands. Fourth, the key indicators that address important professional skills used by engineers (Issues Solutions & Impacts [ISI], Ethics, and Engineering Communication [Comm-Engr]) must be addressed multiple times in at least one of the grade bands. While Teamwork (Team) is an important aspect of engineering, we chose not to include it our measure of comprehensiveness for state standards because it is sometimes difficult to express explicitly in academic standards.

The Cases

With the recent call for engineering to be presented alongside the sciences (NRC, 2012a), it is important to look at the current landscape of engineering in academic standards. Academic standards present a model for what students should know and understand, and in order to provide a holistic picture of this landscape of engineering in K-12 science, two cases will be presented. As stated above, these two cases include a detailed view of the landscape before and after the release of the NGSS. This allows for a comparison of what was in place before the release of the NGSS and what is being put forward in terms of engineering within the NGSS.

Case 1: Landscape of Engineering Present across the Nation Prior to the Release of NGSS

Since engineering is not an entirely new idea and was presented in the previous National Science Education Standards (NSES) under the title of technological design (NRC, 1996), engineering had already begun to be integrated into several states science standards prior to the release of the K-12 Science Framework or NGSS. The analysis of the science standards document from all 50 states prior to the release and adoption of the NGSS provides a view of the landscape of engineering in K-12 science. As mentioned previously, it is important to look at this overview of the landscape because despite sometimes being called national standards, the NGSS will likely not be adopted by all states. Additionally, with the increasing emphasis on STEM and engineering education, it is important to get an idea of the status of engineering in the United States before and after the release of the NGSS. The findings from this first case will provide insight into the types of engineering and the extent to which engineering is included across the U.S. science standards documents prior to the release and adoption of the NGSS.

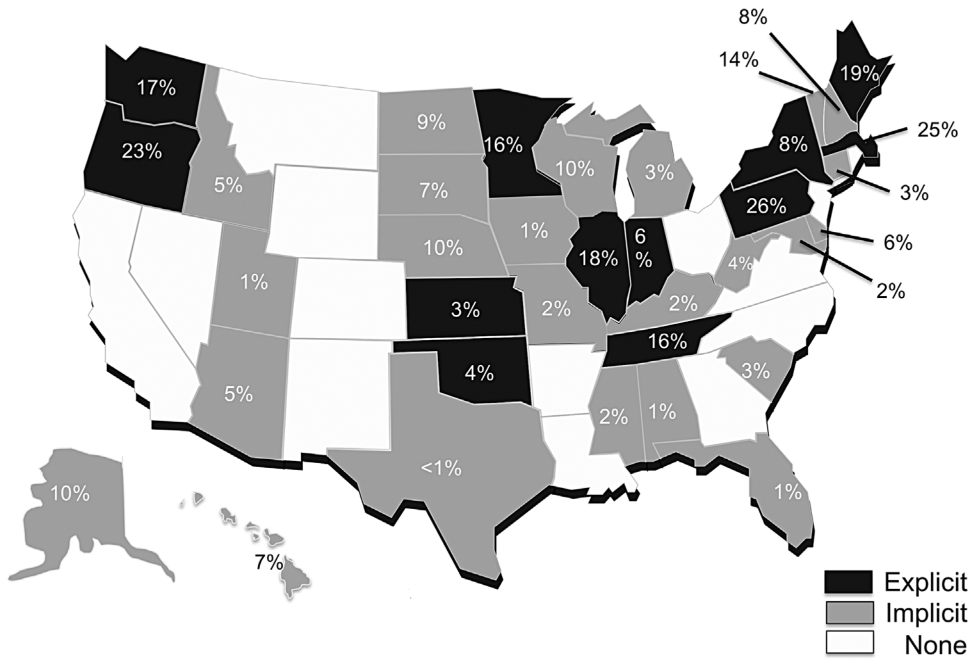

Figure 2. U.S. map of the type and percentage of engineering in science standards. *Note:* Explicit = standards explicitly identified as engineering, Implicit = standards that do not specifically mention engineering, but contain key indicators in an engineering context, None = standards that do not contain engineering in their science standards.

Type and Extent of Engineering Present. Using the *Framework for QEE,* the state science standards documents of all 50 states were assessed to determine the quantity and type of engineering present in the science standards documents across the nation, prior to the release of the NGSS, and according the levels of explicit, implicit, or none (see data analysis above for definitions). The results presented in Figure 2 show that only 12 out of 50 states (24%) explicitly include engineering in their standards. Almost half of the states, 24 out of 50 (48%), were found to have elements of engineering implicitly stated in their standards. There were 14 states (28%) that did not include any evidence of engineering and were therefore classified as "none" in terms of the engineering included in their science standards. It is also important to note that some states, such as Ohio and North Carolina, while they are classified as none in this paper because they do not specifically include engineering in their science content standards, do suggest that engineering and technological design are an appropriate pedagogy to teach science content. A further look at the percentage of standards that contained engineering, seen in Figure 2 below, revealed that the states with explicit engineering addressed engineering in an average of about 15% of their standards, and those with implicit engineering included engineering in only about 5% of their science standards.

There were few states that contained higher percentages of engineering standards, such as Massachusetts (24.93%), Pennsylvania (26.47%), and Oregon (22.58%), which are all states with explicit engineering. However, the majority of the states had 10% or less of their science standards identified as engineering. While this low percentage was especially true for those states with implicit engineering, there were also a number of states with explicit engineering that had smaller percentages of engineering. The breakdown of the percentages included in Figure 2 provide a picture of the amount of engineering identified in the U.S. science standards landscape before the

Table 1
Examination of the type of engineering included in embedded cases prior to NGSS as measured by the key indicators

Number of Key Indicators of Engineering Included	# of States	State
12	3	OR, PA, WA
11	5	ME, MD, IL, MN, NY
10	9	AK, IN, KS, MA, MI, NE, TN, VT, WV
9	4	AZ, CT, MS, NH
8	2	KY, ND
7	4	SC, SD, UT, WI
6	1	DE
5	3	HI, IA, OK
4	1	ID
3 or less	4	AL, FL, MO, TX
None	14	AR, CA, CO, GA, LA, MT, NV, NJ, NM, NC, OH, RI, VA, WY

release of the NGSS identifying that several states had individually made the decision to add components of engineering into their science standards and some to a significant extent.

A further look at the type of engineering present within each of the state's science standards was measured by the number of key indicators from the *Framework for QEE* that were met. These results, presented in Table 1, reveal that there is a large range in the extent to which engineering has been included in standards across the United States. Three out of the 50 states met all 12 of the key indicators and these included Oregon, Pennsylvania, and Washington. Additionally, five states, Maine, Maryland, Illinois, Minnesota, and New York, met 11 out of the 12 indicators. On the other end, a large number of states (22 out of 50) were found to have met less than half of the engineering key indicators within their science standards.

Distribution of Engineering Across Grade Bands. In order to have a better idea of the level of emphasis of engineering throughout K-12 for the 37 states that were identified to have elements of engineering, the data were disaggregated into the grade bands identified in the *Framework for K-12 Science Education* (NRC, 2012a) and the NGSS (NGSS Lead States, 2013). The results showed that out of 1,437 science standards that were identified as containing elements of engineering, these engineering-related standards were fairly well distributed across grade bands. In addition, the presence of key indicators increased across grade bands with more elements of engineering in higher grades, going from 11.2% in K-2 to 34.9% in 9–12. The results are presented in Table 2.

Comprehensiveness of Engineering within the Standards Across Those States with Explicit Engineering. There were four states whose standards present a comprehensive inclusion of

Table 2
Distribution of engineering-related standards within the states across grade bands

Grades	K-12	K-2	3–5	6–8	9–12
Number of Engineering-related standards	1437	162 (11.3%)	324 (22.5%)	403 (28.0%)	501 (34.9%)

Note: Standards not specific to a grade band were not included in the count for any grade band, thus percentages do not sum to 100%.

Table 3
A measure of comprehensiveness in those 12 states with explicit engineering

Comprehensive?	States
Yes	ME, MA, MN, OR
Almost	NY, PA, WA
No	IL, IN, KS, OK, TN

engineering (as described above in the data analysis section) into their science standards: Maine, Massachusetts, Minnesota, and Oregon. Of the remaining eight states with explicit engineering in their science standards, three of those states came close to including comprehensive engineering in their science standards. For example, New York's science standards were only missing evidence of the Ethics indicator in their engineering standards. The science standards in the state of Pennsylvania were missing all of the indicators of engineering at the K-2 level, but otherwise their grades 3–12 science standards met the criteria for comprehensive engineering. The Washington science standards were missing evidence of engineering design, specifically the planning, implementing, testing, and evaluating aspects of the design process (POD-PI, POD-TE) at the K-2 level and had limited evidence of complete engineering design at the high school level. The last five states (Illinois, Indiana, Kansas, Oklahoma, and Tennessee) met the criteria for explicit engineering, but their science standards did not include all of the necessary content to be considered comprehensive. The extent to which the 12 states with explicit engineering have met the second set of criteria for comprehensiveness is presented in Table 3.

Case 2: Landscape of Engineering Present in the NGSS

This second case includes the analysis of the NGSS. This presents a summary of the overall picture of engineering that states will be expected to implement if they adopt the NGSS.

Type and Extent of Engineering Present. Within the NGSS document, there are 208 unique Performance Expectations (PEs). Of these, 42 were marked with an "*", meaning they were intended by the authors of the standards to "integrate traditional science content with engineering through a Practice or Disciplinary Core Idea" (NGSS Lead States, 2013, p. 5). In addition to considering the "*" marking for the identification of engineering-related PEs, the research team assessed each of the 208 PEs for engineering context during the individual coding of the NGSS document. Beyond the 42 explicitly marked as engineering, seven PEs not identified as engineering by the NGSS document itself were determined to meet the research teams' criteria for engineering context, and these PEs were added to the count of engineering-related PEs making a total of 49 PEs (23.6% of all PEs) related to engineering. Additionally, there are 76 Learning Goals (LGs) connected to those 49 engineering-related PEs that were also coded.

The type of engineering present in the NGSS was further explored by identifying the number of key indicators from the *Framework for QEE* that were met through the PEs and LGs within the NGSS. Table 4 summarizes this information. The PEs address 10 of the 12 key indicators identified and the two missing indicators are Conceptions of Engineers and Engineering (CEE) and Teamwork. The LGs address one additional key indicator, CEE, which brought the total for the NGSS to 11 out of the 12 key indicators.

Distribution of Engineering Across Grade Bands. Both the NGSS and the *Framework for K-12 Science Education* documents emphasize the importance of integrating engineering

Table 4
Examination of the type of engineering included in the NGSS as measured by the key indicators

Number of Key Indicators of Engineering Included	NGSS Category
11	Learning Goals (LGs)
10	Performance Expectations (PEs)

Table 5
Distribution of engineering-related performance expectations and learning goals across grade bands within the NGSS

Grades	K-12	K-2	3–5	6–8	9–12
Number of Engineering-related Performance Expectations	49	13 (26.53%)	9 (18.37%)	13 (26.53%)	14 (28.57%)
Number of Engineering-related Learning Goals	76	19 (25.00%)	15 (19.74%)	22 (28.95%)	20 (26.32%)
Total	125	32 (25.60%)	24 (19.20%)	35 (28.00%)	34 (27.20%)

throughout K-12 (NGSS Lead States, 2013; NRC, 2012a). Table 5 presents the distribution of engineering that is found within the 49 engineering-related PEs and 76 LGs from the Foundation Boxes in each of the grade bands in the NGSS. The analysis found that the engineering in the PEs were fairly well distributed across the grade bands with similar number of PEs and LGs represented in each of the four grade bands.

Comprehensiveness of Engineering Standards Across NGSS. The comprehensiveness measure allows for the assessment of a quality K-12 engineering education to go a step further by assessing the PEs and LGs identified for each of the 12 key indicators and across which grade bands these standards were found. The breakdown of the key indicator counts for the PEs by grade band is shown in Table 6 and the key indicator counts for the LGs by grade band is shown in Table 7.

The first criteria for comprehensiveness is the need to address the three key indicators that are the most central to K-12 engineering in all of the grade bands from K-12, and while the PEs address each of the sub-indicators of processes of design in multiple instances in each of the grade bands, EThink is not addressed in grades 3–5 or middle school. The second part of having a comprehensive engineering education is that the key indicators, Conceptions of Engineers and Engineering (CEE), and Engineering Tools and Processes (ETools), which are important to the development of students' understanding of engineering, should be present multiple times in at least two of the grade bands. As mentioned previously, CEE is missing from all of the grade bands, but the ETools indicator is addressed twice in three of the grade bands. The remaining component requires that the key indicators representing professional skills used by engineers should be addressed multiple times in at least one of the grade bands, and these include Issues, Solutions and Impacts (ISI), Ethics, and Engineering Communication (Comm-Engr). While the ISI indicator is well represented, especially in the older grades, and the Comm-Engr indicator is also addressed in multiple grade bands, the ethical considerations relevant to engineering are largely absent. Therefore, the PEs in the NGSS do not represent a comprehensive K-12 engineering education, and there are several areas that would need to be addressed or supplemented in order to meet that criteria.

Table 6
Number of performance expectations by key indicator and grade band within the NGSS

Code	Grade Band			
	K-2	3–5	MS	HS
POD	—	—	1	—
POD.PB	3	2	2	3
POD.PI	6	4	5	5
POD.TE	2	4	4	8
SEM	8	6	8	8
EThink	1	—	—	3
CEE	—	—	—	—
ETool	2	—	2	2
ISI	1	4	6	6
Ethics	—	—	—	1
Team	—	—	—	—
Comm.Engr	2	2	—	2

The inclusion of the Learning Goals, along with the PEs, provides a more comprehensive view of engineering education within the NGSS than just PEs alone. One of the largest additions from the LGs is the broader inclusion of engineering thinking and conceptions of the engineering profession. When looking at how well the LGs address the three indicators central to engineering (Complete POD, SEM, and EThink) across all of the grade bands, evidence of Complete POD was found in three grade bands along with multiple instances of the POD sub-indicators. The key indicator of SEM was found in all four of the grade bands and the EThink indicator was seen in three of the four grade bands. While this amount and distribution was better than what was seen in the PEs, it is still not considered comprehensive. The indicators of CEE and ETools were also more prevalent within the LGs with each of them being present multiple times in at least two of the grade bands. The professional skills' indicators of ISI and Comm-Engr were seen multiple times in at least two of the grade bands, but the limited treatment of engineering ethics (Ethics indicator) precluded the NGSS from being seen as comprehensive.

Table 7
Number of learning goals within the NGSS that met each key indicator broken down by grade band

Code	Grade Band			
	K-2	3–5	MS	HS
POD	1	—	3	2
POD.PB	5	4	3	2
POD.PI	4	2	—	4
POD.TE	2	5	8	2
SEM	3	2	5	9
EThink	3	—	3	9
CEE	3	3	2	5
ETool	3	—	3	4
ISI	1	2	2	4
Ethics	—	—	—	2
Team	—	—	—	—
Comm.Engr	1	2	2	2

When the PEs and the LGs are considered together, then the NGSS is almost comprehensive by our metric. However, it still does not meet our definition of comprehensive due to the fact that neither the PEs nor the LGs address engineering thinking or habits of mind (EThink indicator) anywhere for students in grades 3–5, which is a central aspect of engineering.

Comparative Analysis

The comparison of the two cases presented above, the landscape before and after the release of the NGSS, provide insight into some of the potential changes and similarities with regards to the landscape of engineering in K-12 science education resulting from the increased emphasis placed on engineering in the *Framework for K-12 Science Education* and NGSS. This section will provide a comparative analysis of these two cases organized around the three outcomes presented above and the embedded cases of states that have already adopted the NGSS.

Type and Extent of Engineering Present

The first case provided a snapshot of the national K-12 engineering landscape prior to the release of the NGSS, and through examination of the state science standards documents, there was evidence of engineering in varying degrees in 36 of those states' standards documents. While this suggests that integrating engineering into K-12 science education exists, it is important to note that this presence of engineering was only explicitly called "engineering" or "technological design" in 12 out of 50 states. This also means that 14 of the 50 states had no elements of engineering included in their science standards. Additionally, this analysis found that there was a relatively small percentage of engineering explicitly present (5%) in the science standards documents across all 50 states prior to the NGSS. In contrast, the analysis of the NGSS document revealed that 49 of the PEs and 76 of the related LGs were explicitly identified as integrating traditional science content with engineering. While there were a few states, Massachusetts (24.93%), Pennsylvania (26.47%), and Oregon (22.58%), that were found to have explicitly integrated similar percentages of engineering to what was found in the NGSS, this represents a significant overall shift in the extent to which engineering is included in K-12 science education for those states that choose to adopt the NGSS. This is especially important for the potential changes that would need to take place in those 14 states without engineering in their science standards, if they choose to adopt the NGSS.

Distribution of Engineering Across Grade Bands

When looking at the distribution of engineering across K-12, there is a varying degree of engineering present in the different grade bands in those states that had integrated engineering prior to the NGSS, showing larger percentages of engineering in middle and high school. Additionally, there were several states that did not include or had limited treatment of engineering at the K-2 and 3–5 grade bands. The engineering in the NGSS is well distributed across K-12, with roughly 20–25% of the PEs falling in each of the four grade bands. This equitable treatment of engineering across the grade bands in the NGSS is representative of the claim made in the executive summary that engineering would be integrated throughout the K-12 standards, but also marks a change from what was seen in a majority of those states that had previously adopted engineering.

Comprehensiveness of Engineering Standards

In addition to the extent of engineering that is present in the science standards and within the NGSS, the third measure assessed the comprehensiveness of the engineering that is present in those documents. With 23 out of the 50 states addressing less than half of the indicators and only

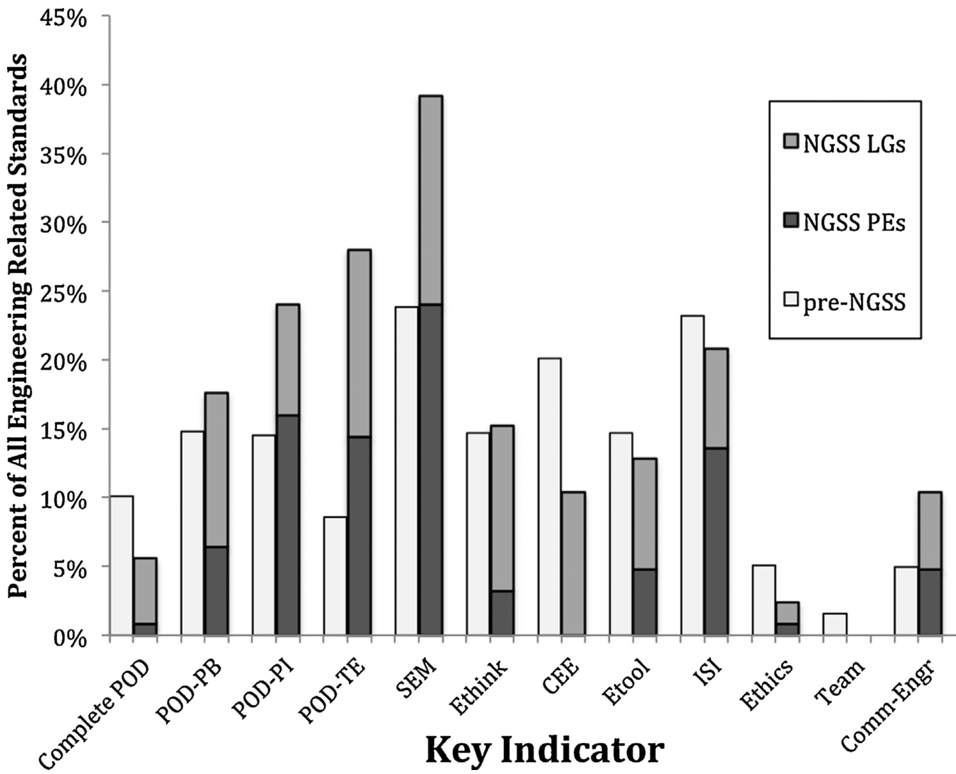

Figure 3. Distribution of key indicators across the 36 states with explicit engineering (pre-NGSS) and within both the NGSS PEs and LGs. Percentages represent the proportion of all engineering-related standards within the respective group.

four out of 50 states meeting the requirements for comprehensiveness, this analysis of the science standards documents before the release of the NGSS suggests that the quality of engineering-related standards is limited in scope due to the fact that many of the states address only a portion of the 12 key indicators captured in the *Framework for QEE*. While the NGSS were also not found to be comprehensive, the standards were close to being comprehensive when including both the PEs and LGs together by addressing 11 out of the 12 key indicators and having a good distribution and frequency across grade bands (with the exception of grades 3–5). Figure 3 provides a comparison of the distribution of the key indicators in the engineering landscape before the NGSS and within the NGSS. When comparing the pre-NGSS landscape of engineering to the PEs and LGs from the NGSS, there is a more robust treatment of the indicators, especially in terms of the three indicators central to K-12 engineering. It is interesting to note that when the PEs are considered without the LGs, the landscape of engineering within the NGSS is not nearly as strong as when the LGs are used to support the PEs. Therefore, in order to ensure a high-quality engineering experience for students, implementation of the NGSS needs to include both the PEs and the related LGs. The analysis found that there is a large emphasis on the sub-indicators of Processes of Design (POD), and on the indicators of Applying Science, Engineering and Mathematics Knowledge (SEM) and Issues, Solutions, and Impacts (ISI) within the NGSS. The assessment of comprehensiveness also highlights the limited presence of the indicators of Complete Processes of Design (POD), Engineering Thinking (EThink), and Ethics in the PEs throughout several of the grade bands, which would need to be strengthened to be considered comprehensive. Therefore, the NGSS present an almost comprehensive engineering education, which is largely different from the collection of state standards prior to the release of the NGSS in terms of the engineering knowledge and skills required of students.

Changes in the Landscape: Adoption of NGSS by States

To further highlight some of the potential changes that would take place with the adoption of the NGSS, the embedded cases of those states, which have already officially adopted the NGSS, will be presented in this section. As of December 2013, eight states (California, Delaware, Kansas, Kentucky, Maryland, Rhode Island, Vermont, and Washington) and the District of Columbia have adopted the NGSS. All eight states that have adopted were lead states in the development of the NGSS. It is also interesting to note that, as of this analysis, none of the four states that were labeled comprehensive above had adopted the NGSS even though all four of them were also lead states in the development of the NGSS.

The two states that will have the most significant change in their science curriculum with regards to engineering are California and Rhode Island. Both of these states had no engineering present in their previous state science standards and have now adopted the NGSS. This suggests that with the fairly comprehensive treatment of engineering that is found in the NGSS, these states will need to shift the ways in which they teach science in order to integrate engineering.

Four of the states that have chosen to adopt the NGSS were classified as implicit engineering in their previous science standards. These states are Delaware, Kentucky, Maryland, and Vermont. For these states, their level of previous implementation differs significantly. Delaware had 6% of their previous standards that addressed engineering through six of the key indicators. While they had engineering included in all grade bands, POD was not addressed deeply in any of the grade bands. For Kentucky, only 2% of their previous standards included engineering; however, these 2% addressed eight of the key indicators. The grade bands for their integration of engineering were primarily middle and high school. While Maryland integrated engineering in only 2% of their standards, they addressed 11 of the key indicators in a high-quality fashion. However, the standards that were present were only in grades K-8. Vermont has both separate science standards which are very light in integrating engineering, but Vermont also has a science, mathematics, technology (SMT) document, which seems to encourage integration of these disciplines. Within Vermont's SMT document, 14% of their standards address engineering through 10 key indicators. For each of these states, having implemented engineering in some manner will likely ease their transition to the engineering requirement of the NGSS in comparison to the states with no previous engineering integration. However, missing grade bands or not as much focus on POD, SEM, or EThink as the NGSS provides may be issues as they transition to the more comprehensive engineering within the NGSS.

There are two states, Washington and Kansas, which have adopted the NGSS and were identified as having explicit engineering in their science standards prior to their adoption of NGSS. With the previous inclusion of explicit engineering standards in these states, the transition to the NGSS will likely be focused on the inclusion of more engineering standards throughout all of the grade bands from K-12. Kansas was not considered comprehensive because, even though there was evidence of 10 out of the 12 key indicators, only 3% of their science standards included engineering, and many of those instances were met by a single standard represented within only one of the four grade bands. This suggests that even though Kansas had evidence of explicit engineering in their previous science standards, their transition will need to focus on scaling up the ways in which engineering is integrated by including larger numbers of science standards in order to reach the level and extent of engineering that is present in the NGSS. The analysis of Washington's science standards prior to their adoption of the NGSS revealed that they are likely to have a transition with minimal changes in regards to the engineering that is present. Prior to their NGSS adoption, approximately 17% of Washington's science standards were identified as engineering, and they were almost comprehensive with only the absence of portions of engineering design, specifically POD-PI and POD-TE, at the K-2 level and with limited evidence of complete engineering design at the high school level.

Implications and Future Directions

If engineering is to be integrated meaningfully with science, as suggested in the *Framework for K-12 Science Education* document (NRC, 2012a) and the NGSS (NGSS Lead States, 2013), these results raise concerns about the differences in the extent to which engineering is currently present in K-12 science and what that will mean for the future with the option for states to adopt the NGSS. This study examined the extent and quality of engineering that was present in K-12 science prior to the release of the NGSS, as well as the engineering that is included in the NGSS, in order to provide insight into what the widespread adoption of the NGSS would mean in terms of potential changes in the way we implement science education in the United States.

There are a number of states that already have elements of engineering in their science standards, and the NGSS does a fairly good job of integrating engineering. However, for a majority of states and their educators, some effort will be needed to overcome the barriers to implementation of engineering, to scale up the elements of engineering to achieve a quality and comprehensive engineering education program within their science curricula, and to make sure engineering is integrated within the science learning environments—not treated as a separate stand-alone topic. For example, the high levels of application of science, engineering, and mathematics (SEM) knowledge in many of the science standards documents prior the NGSS can serve as a foundation for implementing more complete engineering design experiences (POD), which are emphasized in the NGSS, while at the same time providing avenues for students to engage in teamwork (Team) and engineering communication (Comm-Engr). However, it may be difficult for teachers to recognize these potential connections in states that did not have a comprehensive engineering education prior to the NGSS.

The above suggests that there will be significant need for teacher and administrator professional development in order to avoid engineering becoming another topic to be taught (Coffey & Alberts, 2013) and to highlight the interdisciplinary nature of engineering which avoids siloed teaching (Bybee, 2010). For example, Minnesota integrated engineering into their science standards in 2009. The state used Federal Department of Education money to develop extensive statewide professional development for engineering and science integration for both teachers and administrators. One of the nine teacher centers around the state is highlighted at http://region11mathandscience.org, and research on teacher's implementation of their learning objectives has been published by Roehrig et al. (2012) and Guzey, Tank, Wang, Roehrig, and Moore (2014). Examples such as these can serve as models for states that are adopting NGSS. The findings from this study, regarding some potential major changes, support the claims of Roehrig et al. (2012) that state that classroom support and professional development will be needed.

The inclusion of engineering in the earlier grades, especially within the K-2 grade band, is an area of concern as we look towards the adoption of the NGSS. To date, there has been limited treatment of engineering in the earlier grades with regards to implementation and the availability of curricular materials is similarly limited. This suggests that there will need to be additional research and curriculum development in this area to help ensure the successful integration of engineering into the science standards, especially at the earlier grades. Commercial curricula, such as Engineering is Elementary (http://www.eiestore.com/) and ETA Hand-to-Mind STEM in Action (http://www.hand2mind.com/brands/hands-onstandards/hands-onstandardssteminac-tion), and free research-based curricula, such as PictureSTEM (http://www.PictureSTEM.org) and Science through LEGO Engineering (http://www.legoengineering.com/science-through-lego-engineering/), are good places for schools and teachers to start integrating engineering into the science classroom. Furthermore, the analysis of those states that have chosen to include comprehensive engineering within their science standards prior to the release of the NGSS were found to have similar levels of engineering and can, therefore, serve as examples for those states facing potentially major shifts in their science standards as they transition to the NGSS.

Overall, the comparative analysis suggests that the inclusion of engineering in K-12 science standards requires a major change in the way we view K-12 science education in a majority of our states. While engineering is not a new idea in science education, e.g., Standard E: Science and Technology of the National Science Education Standards focused on technological design (NRC, 1996), there is a renewed interest and increased attention being placed on the inclusion of engineering and engineering design due to the NGSS. However, with the increasing emphasis on engineering that is being suggested in the NGSS, it is important to note that as we look towards the adoption and implementation of these standards, there is not an established research tradition of what engineering education at the K-12 level should include or accomplish (Brophy et al., 2008; Chandler, Fontenot, & Tate, 2011; Moore et al., 2014; NRC, 2009). Research on engineering within the context of the NGSS is needed to help shape the scope and sequence of engineering design and engineering thinking, as well as engineering classroom assessment practices, in the K-12 science curriculum.

As researchers, practitioners, and policymakers start work on the adoption and implementation of the NGSS, it will be important to continue to develop the research base on what engineering looks like in K-12 settings, particularly when integrated into science classrooms. This analysis will help to address some of the questions about the integration of engineering into science by describing the landscape with regard to engineering education at the state level and across the nation before and after the release of the NGSS. These results identify that several states were providing high quality engineering education prior to the release of the NGSS, but there are also several opportunities to strengthen engineering education at the K-12 level as suggested in the *K-12 Framework for Science Education* (NRC, 2012a) and the NGSS (NGSS Lead States, 2013). Additionally, the calls from international reports also suggest that integration of engineering is needed in precollege education. As all of us are working toward educating our students by integrating engineering within science, we can learn from one another and build a solid research base of effective practices, programs, curricula, and professional development.

Precollege engineering education is vital for developing technological literacy within our society, as well as a future generation of engineers and problem solvers that can provide new technological innovations to solve the complex problems of tomorrow. As we look towards the future of engineering within precollege classrooms, it is important to build off of the current landscape and work towards an agreed upon consensus of K-12 engineering education if we are to avoid the pitfalls of previous shifts in science standards (Penuel & Fishman, 2012). This is imperative if we are to move forward with the meaningful integration of engineering into our science standards, instruction, curriculum, and practice. Lessons learned from the states that already have engineering as a part of their science standards will help guide those who will be implementing engineering either through increased engineering in locally developed standards or through the adoption of internationally benchmarked standards such as the Next Generation Science Standards.

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