Evaluation of Online Teacher and Student Materials for the Framework for K-12 Science Education Science and Engineering Crosscutting Concepts

by

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ABSTRACT

The National Research Council developed and published the *Framework for K-12 Science Education*, a new set of concepts that many states were planning on adopting. Part of this new endeavor included a set of science and engineering crosscutting concepts to be incorporated into science materials and activities, a first in science standards history. With the recent development of the *Framework* came the arduous task of evaluating current lessons for alignment with the new crosscutting concepts.

This study took on that task in a small, yet important area of available lessons on the internet. Lessons, to be used by K-12 educators and students, were produced by different organizations and research efforts. This study focused specifically on Earth science lessons as they related to earthquakes. To answer the question as to the extent current and available lessons met the new crosscutting concepts; an evaluation rubric was developed and used to examine teacher and student lessons. Lessons were evaluated on evidence of the science, engineering and application of the engineering for each of the seven crosscutting concepts in the *Framework*. Each lesson was also evaluated for grade level appropriateness to determine if the lesson was suitable for the intended grade level(s) designated by the lesson.

The study demonstrated that the majority of lesson items contained science applications of the crosscutting concepts. However, few contained evidence of engineering applications of the crosscutting concepts. Not only was there lack of evidence for engineering examples of the crosscutting concepts, but a lack of application engineering concepts as well. To evaluate application of the engineering concepts, the activities were examined for characteristics of the engineering design process. Results

indicated that student activities were limited in both the nature of the activity and the quantity of lessons that contained activities. The majority of lessons were found to be grade appropriate.

This study demonstrated the need to redesign current lessons to incorporate more engineering-specific examples from the crosscutting concepts. Furthermore, it provided evidence the current model of material development was out dated and should be revised to include engineering concepts to meet the needs of the new science standards.

DEDICATION

I dedicate this dissertation to my Aunt Paula Moseley, for whom I would not have found the confidence to pursue my doctorate and the strength to overcome my challenges.

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Although there are many people I could acknowledge for their help, guidance and support, I would like to point out a few that have gone above and beyond the call of duty.

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INTRODUCTION

Background of the Study

In 2010 The National Research Council (NRC), issued the first draft of the *Framework for K-12 Science Education* (*NRC Framework*) for public consideration. The framework which was the product of years of consideration starting with the Carnegie Corporation calling for a common set of science and engineering standards in K-12 education. The *NRC Framework* written by the National Research Council in 2011 (NRC, 2011) was to help identify and develop a means by which standards for science and engineering could be produced to meet the needs of the next generation of students. In 2011, the NRC released the final draft of the *NRC Framework* and it was made public for reference and standards development. In addition to the commissioning of the NRC to develop the *NRC Framework*, the Carnegie Foundation also charged Achieve Incorporated, to develop a national set of science standards to be framed by the *NRC Framework* (NRC, 2011). Achieve made the final set of science and engineering standards available in 2013, at which point states will adopt and revise the standards in order to implement them at some point in the future. With the new standards will come the need for materials that will align to not only the standards, but also the *NRC Framework* from which they were created (NRC, 2011). Within the *NRC Framework* were the crosscutting concepts, a set of guiding principles to be used to help connect ideas across disciplines and grade levels. Although the crosscutting concepts themselves were not meant to add additional content, they were there to help guide in the development of standards, curricula, and materials to enable students to understand a more broadened understanding across science, technology, math, and engineering as they related to one another (NRC, 2011).

Statement of the Problem

As observed by a Google search for Earth science earthquake lesson plans and student materials, the number of results that were returned is too many to express, as it exceeded the 50,000 results limit set by Google. The question becomes how many of these items were of a quality nature that could be used by teachers to meet the new standards produced by the *NRC Framework*? Furthermore, how many of these items exhibit the necessary traits of the crosscutting concepts, more specifically with the engineering crosscutting concept? These questions exhibit the current issue with the freely available resources to teachers and students on the Internet. Because the *Next Generation Science Standards* (*NGSS*) have just been released, current teacher materials do not necessarily reflect attributes that aligned to the *NRC Framework* or the *NGSS*. It will be essential for teachers to be able to find materials on the Internet that not only will assist in the presentation of a subject matter, but to the degree that they provide the appropriate content to be considered successful. As of this point, there has been no published study performed on the content analysis of Internet materials as they relate to the *NRC Framework*. The study will be conducted such that the research will look at materials produced in earth science for K-12 teachers, and determining the extent by which they align to the *NRC Framework*.

It is important to understand what the crosscutting concepts were, and how they were defined. The crosscutting concepts represent a philosophy of connecting ideas across different disciplines. In the instance of the *NRC Framework*, these ideas and disciplines were represented by different science and engineering principles. Table 1, illustrates the crosscutting concepts, their definitions and their relationship to engineering themes (NRC, 2011).

Table 1
NRC Framework Crosscutting Concepts and Engineering Examples

Crosscutting Concept	Description	Engineering Example
Patterns	Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Patterns in manufacturing processes, patterns in traffic along highways and streets, patterns in equipment failure.
Cause and Effect: Mechanism and Explanation	Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediate d. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.	Designs produced by different effects. Cause and effects such as constant freezing and thawing on roadways and bridges. Cause and effect of water erosion or mechanical fatigue over prolonged periods of time.
Scale, Proportion, and Quantity	In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.	The building of scale models to represent functional projects.
Systems and System Models	Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing	The development and understanding of different systems using different parts and items and their interaction with each other.

	ideas that are applicable throughout science and engineering.	
Energy and Matter: Flows, Cycles, and Conservation	Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.	The laws of thermodynamics and laws of conservation of energy in application and use, such as friction of fluid through a pipe.
Structure and Function	The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	The means and methods by which a mechanism works, and the structure that binds it together such as a bicycle.
Stability and Change	For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	The wear and tear on gears in a machine, and other mechanical devices over a period of time.

Note. Descriptions are quoted from National Research Council. (2011). *A NRC Framework: Practices, crosscutting concepts, and core ideas*. Washington, D.C: The National Academies Press, p. 84.

Purpose of the Study

It was because of these questions and problems that have been identified that we looked at and evaluated some of these materials to determine if they meet the standards necessary and required by the *NRC Framework* to be considered useful items for teachers and students as they related to engineering applications of the crosscutting concepts. The study looked at materials produced and distributed via the internet from several different sources, including: university research, government agencies, professional organizations, commercial organizations and nonprofit organizations. Such information will help in the development and evaluation of teacher materials for the expectations of standards that will be developed from the *NRC Framework* in states all over the country. Currently, 26 states are part of a nationwide endeavor to create a national set of science standards that include for the first time engineering standards (NRC, 2011). This study will also provide an evaluation tool that can be used in assessing other materials across other disciplines and curricula. The assessment tool has been designed to be malleable, in an effort to allow it to be more universally used.

Research Questions

To what extent were the crosscutting concepts of the *NRC Framework* present in Earth science teacher materials available on the internet? To what extent were the engineering crosscutting concepts of the *NRC Framework* present in Earth science teacher materials available on the internet? What themes were present in the Earth science teacher materials available on the internet?

Research Design

This research study was designed using a mixed-methods approach. Initially, the research was conducted using quantitative analysis, by which was used a material evaluation rubric to analyze Earth science earthquake teacher and student materials gathered from the Internet. The results of the quantitative analysis helped to drive the second portion of the qualitative analysis using grounded theory to identify common themes from the materials. Five different models for curriculum assessment and evaluation were considered. The five evaluation models included: a program evaluation strategy produced through the Accreditation Board of Engineering and Technology (ABET, 2011), which evaluated engineering programs through self-assessment and evaluation; the table specifications method as produced by Crocker and Algina, from their book *Instruction to Classical and Modern Test Theory* (2006) and a previous study that the researcher did using this method (Schwab, 2011); a mixed methods evaluation system produced by the National Research Council from their study on evaluating curricular effectiveness in K-12 mathematics evaluations (NRC, 2010); a measurement of fidelity in implementation as primarily defined by Carol O'Donnell (O'Donnell, 2008) and supported by several other studies (Kimpston, 1985; Gersten et al., 2009); last, the National Science Foundation's Advanced Technology Education program using the Technical Education Curriculum Assessment (TECA) model (Keiser, Lawrenz, Appleton, 2004). Although these methods provided useful components that could easily be used to evaluate curriculum material and methods, a decision to focus primarily on the two that were thought to be most beneficial to the study.

The two models that were chosen to focus attention on were O'Donnell's measurement of fidelity (O'Donnell, 2008) and implementation and the National Science Foundation's Advanced Technology Education program using the TECA framework (Keiser, Lawrenz, Appleton, 2004). Each of these models allowed a closer look at the programs and their effectiveness in transferring information along with their ability to implement such tools and content in the classroom. This was not to say that the three other options that were considered would not have sufficed in adequately providing enough information or data in being able to aid in the research, it was the researcher's opinion that those two had the best chance of being successful in a given timeframe, and with the resources at hand.

Chapter 2

REVIEW OF THE LITERATURE

Introduction

This chapter will first present a brief description of each of the documents and highlight certain portions of them. The documents included: the *NRC Framework*, the *National Science Education Standards (NSES)*, and the *American Association for the Advancement of Science Benchmarks (AAAS Benchmarks)*, the Accreditation Board for Engineering and Technology (ABET), and the *Common Core State Standards (CCSS)*. The *National Science Education Standards*, *Common Core State Standards* and the *Next Generation Science Standards* were all describe as standards as they contained specific concepts that students needed to know, understand and demonstrate at given grade levels. While the *American Association for the Advancement of Science Benchmarks* was classified as benchmarks because they described what goals should be progressed towards by students at the end of grade bands for students to have achieved science literacy. The Accreditation Board for Engineering and Technology represented criteria that outlined the competencies needed by undergraduate students to graduate. The criteria, although they called for mastery of topics needed to graduate, they were too broad in scope and time frame to be considered standards.

Next, there will be a discussion regarding engineering traits that the researcher found in each of the documents, or how a document did not necessarily fit into this evaluation. From there, the researcher will explain the relevance and commonalities in these engineering traits amongst the documents. The next section will discuss where these documents were taking us as they related to our engineering themes in the future.

Finally, the researcher took a closer look at the *NRC Framework* and how it improved upon, or least differed from the current *NSES*. The last portion of this chapter will focus on material and program evaluation frameworks (NRC, 1996, 2011).

The Evolution of Science Standards

Historical Science Standards

The *American Association for the Advancement of Science Benchmarks* (*AAAS Benchmarks*). The *AAAS Benchmarks*, also known as the *Benchmarks*, was the result of a second-generation publication from the *American Association for the Advancement of Science Project 2061*, was published in 1993 and revised in 2009 (AAAS, 2009). The first document from Project 2061 was called *Science for All Americans* (AAAS, 2009) and set up the core ideas and concepts for what an adult should know in science literacy in 1989. It was this document that was used to build the *AAAS Benchmarks* (AAAS, 2009). The *AAAS Benchmarks* was written to help produce a set of learning objectives to be met by students in different grade arenas (AAAS, 2009). These arenas or benchmarks were intended to give school districts and states the opportunity to build standards to meet the needs of these local agencies in order to improve science education. The *AAAS Benchmarks* was finalized in 1993 and since then was updated as recently as 2009; however, such updates were strictly in terminology and not in content (AAAS, 2009). It was the work of the AAAS to produce the benchmark of science literacy through the Project 2061 program. Such development came from teams of school teachers, administrators and curriculum specialists with the assistance of scientists for information accuracy (AAAS, 2009). The *AAAS Benchmarks* focused on science literacy in terms of scientific inquiry to help support students in their understanding and learning of science, mathematics and technology. More recent and future goals of the *AAAS Benchmarks* were set to help introduce additional resources (AAAS, 2009).

The AAAS characterized the *Benchmarks* with the following different premises: First, the *Benchmarks* were a report from a cross section of practicing educators, including teachers, administrators, curriculum writers and scientists. The *Benchmarks* were not a curriculum, they were not designed to take the place of curriculum or even be a set of standards; but instead, a guide to help build them (AAAS, 2009). The *AAAS Benchmarks* were a series of specific science literacy goals that could be manipulated or organized to suit the organization creating the standards that surrounded them. The *AAAS Benchmarks* represented thresholds of what students should know at different grade segments. The *AAAS Benchmarks* represented a common core of learning that would contribute to the understanding of science literacy for all students. The *Benchmarks* reduced and avoided technical language, to be more easily understood by all students. However, the *AAAS Benchmarks* created a rather ambiguous set of instructions as to how to achieve these goals. The *AAAS Benchmarks* were developed by research and were a living document to be further developed, and represented a tool in the toolbox designed by the Project 2061 program (AAAS, 2009). In creating the *Benchmarks* the AAAS suggested that they be used by educators to help explore the concept of science literacy as it related to education, to gauge how well a current curriculum was meeting science literacy needs, to help test writers gauge the information being examined, to help universities and colleges develop teacher training programs, and to help states and districts write standards and curriculum to meet the goals of the *Benchmarks* (AAAS, 2009).

The *AAAS Benchmarks* included the following twelve primary core ideas: the nature of science, the nature of mathematics, the nature of technology, the physical setting, the living environment, the human organism, human society, the designed world, the mathematical world, historical perspectives, common themes, and habits of mind. The first three sections, addressing "the nature of" core ideas, identified the benchmarks for the different grade groupings including kindergarten through grade two, grades three through five, grades six through eight, and grades nine through twelve. They basically stated what students should know by the end of those segments, they included the original 1993 version of the benchmark statements along with a current version of benchmark statements (AAAS, 2009). This same basic method was expressed throughout the entire rest of the benchmarks, where the physical setting discussed physical sciences, the living environment discussed biology, as did the human organism. The chapter on human society and design focused on the economic and political aspects of science and technology in the mathematical world which discussed mathematical concepts. The last chapter, "habits of mind", was a benchmark designed to include problem solving skills, and critical responses across subject matter problems in uniting different problem-solving strategies (AAAS, 2009).

Current Science Standards

The *National Science Education Standards* (*NSES*). The *NSES* were the result of a multiyear study in science education, composed by the National Academy of Science and more specifically the National Research Council to develop a national set of science standards that focused on science literacy through science inquiry-based learning. The *NSES* goal was to help streamline science education across the nation, and to give what was considered at the time the best practices of science education. In 1996 the *NSES* was completed and distributed to the states for use in school districts. Significant proponents of the *NSES* included the National Science Teachers Association and the American Association for the Advancement of Science, who also provided input in the development of the standards (NRC, 1996). Since 1996, the *NSES* has existed as a national set of standards for science education. The goals for the *NSES* were to help students understand and become more knowledgeable about the natural world, to be able to use scientific processes properly, to be able to hold knowledgeable debates within the scientific community, and to increase economic productivity through scientific literacy (NRC, 1996).

The *NSES* were presented in seven chapters, that included: principles and definitions; science teaching standards; standards for professional development for teachers of science; assessment in science education; science content standards; science education program standards; and science education system standards (NRC, 1996). The chapter on principles and definitions laid out a basic outline for terminology and expectations of the standards themselves and how they should be interpreted when examining the specific standards. The science teaching standards chapter was broken up into six areas. They included: the planning of inquiry-based science programs, the actions taken to guide and facilitate student learning, the assessment made of teaching and student learning, the development of environments that enabled students to learn science, the creation of communities of science learners, and the planning and development of school science programs. This section was dedicated to show what science teachers were expected to know and be able to demonstrate. The next chapter, professional development standards, included the following four areas: the learning of science content through inquiry; the integration of knowledge about science with knowledge about learning, pedagogy, and students; the development of understanding and ability for lifelong learning; and through coherence and integration of professional development programs. This section was dedicated to helping facilitate professional development for teachers of the science standards. The chapter on assessment standards, included five areas, which were the consistency of assessments with the decisions they were designed to inform; the assessment of both achievement and opportunity to learn science; the match between the technical quality of the data collected and the consequence of the actions taken on the basis of those data; the fairness of assessment practices; the soundness of inferences made from assessments about student achievement and opportunity to learn. This chapter was to provide the criteria for which assessments would be judged for quality of practice (NRC, 1996).

In the next chapter on science content standards, the standards were outlined as to what the student should know, understand, and be able to re-create in the natural sciences throughout their K-12 educational career. The science standards were divided up into eight core ideas. They included: identifying concepts and processes in science, science as inquiry, physical science, life science, Earth and space science, science and technology, science in personal and social perspective, and the history and nature of science. The first core idea was expressed for all grade levels undivided, for the reason they believed it was a process that was developed over the course of the student's career. The other core ideas were then broken up into category grade segments, which were kindergarten through fourth, fifth through eighth, and ninth through twelfth grade (NRC, 1996).

The last two chapters included science education program standards and science education system standards. Science education program standards were broken down to six areas: the consistency of science programs with other standards and across grade levels; the inclusion of all content standards in a variety of curricula that were developmentally appropriate, interesting, relevant to students lives, organized around inquiry, and connected with other school subjects; the coronation of the science program with mathematical education; the provision of appropriate and sufficient resources to all students; the provision of equitable opportunities for all students to learn the standards; the development of communities that encouraged, supported, and sustained teachers. This standard was used to help describe the conditions required for quality science programs at school. The last chapter was devoted to science education system standards. This included seven topic areas: the congruency of policies that influence science education with the teaching, professional development, assessment, content, and program standards; the coronation of science education policies within and across agencies, institutions, and organizations; the continuity of science education policies over time; the provision of resources to support science education policies; the equality embodied in science education policies; the possible unanticipated effects of policies on science education; and the responsibilities of individuals to achieve new vision of science education portrayed in the standards. This standard was used to help judge the overall quality of the science education system at hand (NRC, 1996).

The *Common Core State Standards (CCSS)*. According to the Centers on Education Policy, the *CCSS* were put together by the National Governors Association (NGA) with support by the Council of Chief State School Officers in 2010 (NGA, 2010), and with design to provide states, school districts and educators a more effective set of standards in improving the literacy of students in the language arts and mathematics (NGA, 2010). The current document of the common core standards were developed from the college and career readiness standards in reading, writing, speaking, listening, and languages as well as in mathematics. The standards were designed not only for English language arts but also literacy in history/social studies, science, and technical subjects. The objective of the common core State standards was to support education and developing 21st-century literate people in the United States. The standards attempted to seek a wide, deep, and thoughtful engagement with literary and informative text that built knowledge, and larges good experience and provided for a broader world view. The standards defined a successful student as someone who had skills in reading, writing, speaking, and listening that they considered the foundation for creative and purposeful expression in language. The common core standards were developed for K-12 education with specific, detailed standards within grade levels. The *CCSS* focused on results and not the means by which to get there, they considered themselves an integrated model of literacy with research and media skills blended into the standards. The common core standards were devised such that by grade four, 50% of the attention should be spent on literacy while the other 50% were spent on information. By grade twelve, 30% of the efforts were spent on literacy while 70% were spent on information (NGA, 2010). The *CCSS* did not cover the specifics as to how teachers were to teach, what specifically needed to be taught, advanced work for students who exceeded the standards, materials needed to support the standards, appropriate support for English language learners or what is specifically considered for college or career readiness. The *CCSS* relied heavily on assessments, with valid evidence (NGA, 2010).

The standards comprise three main sections: the first section is a kindergarten to fifth grade portion, and to core ideas for grades six through twelve. The two primary areas for six through twelfth grade include standards for English language arts, and standard for literacy in history/social studies, science, and technical subjects. Emphasized in both systems of standards are reading and writing, and downplay content-specific material. The section for literacy in history/social studies, science, and technical subjects was broken down into two subsections: reading and writing (NGA, 2010).

The Accreditation Board of Engineering and Technology (ABET). ABET was an accreditation agency responsible for maintaining the criteria for accrediting engineering programs at all postsecondary schools (ABET, 2011). ABET was not responsible for developing any form of standards, much less those to be used in K-12 education. ABET did not have any K-12 education criteria or accreditation authority for engineering programs that existed in the K-12 system. They did provide student outcome expectations for graduating from an engineering program at postsecondary institution (ABET, 2011). These student outcomes could be considered a framework for standards and a basic guide to help K-12 education understand what would be required of students at the university level. The accreditation criteria were set up to be reviewed for each individual engineering discipline, with only a handful of generalized outcome expectations. The student outcome expectations included eleven objectives that must be met by the University for each student. These objectives included: (a) an ability to apply knowledge of mathematics, science, and engineering; (b) ability to design and conduct experiments, as well as to analyze and interpret data; (c) ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; (d) ability to function on multidisciplinary teams; and ability to identify, formulate, and solve engineering problems; (e) an understanding of professional and ethical responsibilities; (f) ability to communicate effectively; (g) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context; (h) a recognition of the need for, and ability to engage in life-long learning; (i) a knowledge of contemporary issues; (j) and ability to use the techniques, skills, and modern engineering tools necessary for the engineering practice (ABET, 2011).

New Science Standards

The *Framework for K-12 Science Education* (*NRC Framework*). The *NRC Framework* was a project by the National Research Council under the direction of the National Academies, funded by the Carnegie Corporation, and was published in 2011. The *NRC Framework* was used to develop the *NGSS*. According to the *NRC Framework*, there was a strong desire to build a new approach to K-12 science education in the United States that would also incorporate engineering concepts and themes. The *NRC Framework* was designed by a committee of STEM professionals and educators alike which determined that there were three major dimensions in science education. These dimensions included: scientific and engineering practices, crosscutting concepts that tie science and engineering through application of common ideas, and four core disciplinary areas. The four core areas included: physical sciences; life sciences; Earth and space sciences; and science, engineering and application of science. This new framework mandated that science and engineering be integrated throughout the standards and curriculum. Another major difference in this new framework was the adoption of the term “practices” to absorb and expand beyond “science inquiry” (NRC, 2011).

The basis of the framework was in fact the three dimensions of scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. The first dimension, scientific and engineering practice, looked at why they considered the change from inquiry-based learning to the practice of learning. They considered eight practices to be significant in the learning of K-12 science, they included: asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations and designing solutions; engaging an argument from evidence; and obtaining, evaluating and communicating information. The move to emphasize practice over inquiry was to help get away from the notion that inquiry-based science was a formula to follow whereas practice meant to become a participant of science learning. There was a great emphasis within the first dimension to discuss the differences and commonalities between scientists and engineers (NRC, 2011).

The second dimension, crosscutting concepts, was the attempt to bridge engineering and science ideas together. In the second dimension of crosscutting concepts, they identified seven crosscutting scientific and engineering concepts that were important. They included: patterns; cause and effect of mechanisms and explanation; scale, proportions, and quantity; systems and system models; energy and matter of flows, cycles and conservation; structure and function; stability and change. Each of these crosscutting concepts gave a relationship between science and engineering and how they should be approached at different grade groupings. It was these concepts that the researcher will use to identify themes in engineering within this document and others (NRC, 2011).

The third and final dimension of the framework discussed the disciplinary core ideas or more specifically it discussed the concepts within physical sciences, life sciences, Earth and space sciences, and the last category engineering, technology and applications of science. Each of those individual core concepts was then broken down further into more specific ideas and subject content appropriate for each core idea and at different grade groupings. These disciplinary core ideas did not express a lot of crossover between disciplines and were relatively isolated to their specific concept. Each of these discipline sections read like a science textbook of the appropriate material in the appropriate grade range. They were written so that standards could be made from them as they were merely there to express the broad information range to be covered within that grade range. Each piece of broad information was then used to build specific standards to meet the criteria of that information (NRC, 2011).

Standards Summary

In 1985 with the passing of Halley's Comet, Project 2061 (the year Halley's Comet will next appear) was commissioned by AAAS as a long-term initiative to help develop our nations understanding and literacy of math, science, and technology (AAAS, 2009). The result of Project 2061 was the development of the science *Benchmarks* in 1993. The *Benchmarks* were intended to help school districts and states in developing their own standards by giving them a series of benchmarks which students should meet at different grade groupings. The *Benchmarks* were not designed to be used as standards, but only as a guide in developing standards (AAAS, 2009). In 1998, running concurrently with the AAAS effort, was an effort by the National Academy of Science to develop a national set of science standards. The *NSES* were published in 1996. The *NSES* were designed to produce the first national set of science and technology standards to be used in guiding states and school districts in the production of their own standards (NRC, 1996). These two documents y shared several similarities, but also contained several major differences. The *Benchmarks* were created to be a guide in developing standards in the fields of math, science and technology. The *NSES* were standards to be used in the areas of science and technology education, with math being a tool but not a standard addressed by the *NSES*. The most recently adopted standards were the *CCSS*, which focused on literacy in reading, writing and mathematics. The *CCSS* were not designed to address science, engineering, or technology (NGA & CCSSO, 2010). The *NRC Framework*, which was published in 2011 represented the next generation of science standards. Like the *Benchmarks* and *NSES*, the *NRC Framework* focused on developing a national set of benchmarks and standards in the areas of science and technology, with the added concept of engineering and science practice (NRC, 2011). It was the addition of engineering as a standard and a conceptual shift from science inquiry to the practice of science that gave the *NRC Framework* a new face in science standards (NRC, 2011).

Engineering Themes in the Standards

Before looking at each of the documents for themes of engineering, the first discussion will define the themes of engineering. According to the Carnegie Foundation, from the book *Educating Engineers*, there were seven basic themes that were used to identify engineering-based concepts. The seven themes included theoretical tools, both math-based and conceptual, fundamental design concepts, operational principles and normal configurations; criteria and specifications; quantitative data, practical considerations; process-facilitating strategies, contextual and normative knowledge (Sheppard, Macatangay, Colby & Sullivan, 2009). The first, theoretical tool was the use of mathematical models and knowledge of scientific theories integrated with intellectual concepts. For fundamental design concepts, it was the ability to understand how individual parts work together to provide a whole. The theme criteria and specifications referred to technical criteria designated to a device or technologies which could include performance criteria. Qualitative data represented the physical properties or quantities needed in formulas that were used to demonstrate the performance of devices and technology. Practical considerations were those ideas for which one could learn on the job and could include ideas such as “rules of thumb.” Process facilitating strategies incorporated the idea of communications management and leadership and the knowledge thereof (NRC, 2010). These examples and definitions were broad in nature, as they pertained to many different disciplines within engineering as well as the different practices of engineering.

One of the major aspects of the *NRC Framework* was the idea of engineering design and the design process. According to ABET, the fundamental elements of the engineering design process included the following six primary categories. The six categories included: establishment of the objective and criteria, synthesis, analysis, construction, testing and evaluation (ABET, 2011). The engineering design process was not a linear system where one started at the beginning of having an objective and then moved to the end goal of having the evaluation of a product, but a spiral of these events happening over and over again in order to refine and perfect the product or outcome (Sheppard, Macatangay, Colby, Sullivan, 2008). It was this notion of a cycle in engineering design that helped lend the development of the *NRC Framework* and its framework for utilizing engineering in the Next Generation Science Standards. Furthermore, it was one of the guiding principles of changing science as exclusively inquiry-based learning to that of a practice of science learning that incorporates inquiry among other practices (NRC, 2011).

It was because there was such a broad spectrum of ideas and theories to describe themes of engineering that the researcher will use those presented in the *NRC Framework*. Because the *NRC Framework* is a document that was specifically designed to incorporate engineering into the new science standards, there were numerous instances where engineering themes were not only identified, but boldly introduced and conceptualized into the framework at all levels (NRC, 2011). These themes were refined from the National Research Council's document; *Standards for K-12 Engineering Education* (NRC, 2010), in which it set the criteria for what defined engineering. They described the criteria of engineering as constraints and specifications, along with other important ideas. According to this document the definition of engineering was described as "design under constraints" and the laws of nature are considered the most fundamental of these constraints. It described engineering as science of the future, where engineers concerned themselves with ideas such as systems, modeling, perspective and analysis, optimization, and trade-offs (NRC, 2010). The *NRC Framework* document which was designed in three parts called dimensions, identified the first dimension as "science and engineering practices." It was these practices that will be used to compare the other documents for engineering themes as they were developed with reference to the National Academy of Engineering and therefore will be considered to be a valid reference to "engineering themes." These themes include: asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and conceptual thinking; designing solutions; engaging an argument from evidence, and obtaining, evaluating; and communicating information. It is these eight themes that were used to identify themes in other documents to help maintain a sense of uniformity and cohesive evaluation (NRC, 2011).

Themes Presented by a *NRC Framework*

As mentioned above, an innovation of the *NRC Framework* was to incorporate engineering concepts, themes and ideas into every aspect of the science learning experience. One of the primary reasons for the use of the term practice was to be able to show that science, along with engineering was learned through the process of practicing knowledge, skills and curiosity. Identifying themes within the framework could be expressed at all levels. Starting with a major portion of the framework titled crosscutting concepts, where the notion was to integrate not only all disciplines of science but that of engineering as well. They considered the seven crosscutting scientific and engineering concepts a pivotal moment in curriculum development (NRC, 2011). The ability to link patterns in a scientific and engineering world could be as simple as linking the idea of the breakdown of perhaps DNA in both biology and genetic engineering. The next concept, cause-and-effect, used an integrated approach to science and engineering, considered fundamental to physical interactions that took place to create consequences on a system.

These types of hybrid interactions between science and engineering were well defined in all of these crosscutting concepts as provided by the *NRC Framework*. The other crosscutting concepts included: scale, proportion and quantity; systems and systems models; energy and matter of flows, cycles, and conservation; stability and change; structure and function. It was the purpose and goal of the *NRC Framework* to introduce all of these engineering terms into the standards which related to the core ideas that were set, including: the physical sciences, life sciences, and Earth and space sciences. They also created a specific set of core ideas aimed specifically at engineering and technology. This segment of the *NRC Framework* set up specific standards to be related to engineering and technology. The first core idea or generalized standard was titled engineering design. This one main idea provided subsections which included the finding and delimitating of an engineering problem, developing possible solutions and optimizing the design solution. Although this was a broad idea for the initiative of developing standards, it specifically incorporated the primary idea and definition of engineering, and design. Even the second core idea, linking engineering, technology, science and society provided substantial ideas and themes in engineering. Those themes included the impact on society and the natural world (NRC, 2011).

Themes presented by the *NSES*

The *NSES* were developed by the National Research Council in 1995 with a focus on inquiry as a way of learning science. Inquiry-based learning and the engineering process have much in common: both involve identifying a problem; developing a method by which to study and one or more methods to correct it, and testing of the solution and redesign when necessary. It was for this reason that there will always see a small amount of crossover between the engineering process and inquiry-based learning. Specifically for the *NSES*, there are some very specific engineering themes that were present within the standards. The major themes that manifest themselves in the *NSES* and transcended the grade levels are: systems, order, and organization; evidence, models, and explanation; consistency, change, and measurement; evolution and equilibrium; form and function. Each one of these themes could be linked to an engineering concept and therefore could be treated as engineering themes. Although the authors of the *NSES* did not specifically state that they were engineering themes, they did provide evidence to show that their intentions could be considered as such. In looking at the concept systems, order, and organization concept, they discussed the idea of being able to recognize closed and open systems, which is a major part of an engineering system analysis. The authors discuss how such systems help in developing knowledge that influence other factors and objects that affect systems and events. Within the concept of evidence, models, and explanation, they discuss how models help engineers understand how things work, and as a result, these were considered a pivotal part of the *NSES*. For consistency, change, and measurement, they discussed the need to understand scales in systems that help in understanding dimensions. With form and function, they consider the complementary aspects of objects and systems and the natural and designed world, which in turn foster the engineering principle of change for the betterment of humanity.

Within the grade level of five through eight, the authors of the *NSES* identified several more engineering themes that one could consider. The second of the content standards is to be able to identify the question that needed to be answered and investigated. This was equivalent to the engineering theme of being able to identify the problem needed to be addressed. The third content standard, to design and conduct a scientific investigation was equivalent to the engineering theme of again developing the problem. The fifth content standard, entitled developing description, explanation, predictions, and models using evidence is also shared by engineering. The high school portions of the standards share the characteristics with the five through eighth grade standards. They added on top of that systems and cycles which again, are very powerful tools in engineering. In addition to the systems and cycles, they include more specific content to their standards. Under the abilities of technological design category it is stipulated that students needed to be able to; identify a problem or design an opportunity, propose designs and choose between alternative solutions, implement a proposed solution, evaluate the solution and its consequences, and communicate the problem, process, and solutions. All of these are themes characteristics of engineering as well as science. Truly the only thing that these lacked was a direct correlation to engineering (NRC, 1996).

Themes presented by *AAAS Benchmarks*

This document was set up in such a manner that it did not reach specific standards but implied a set of benchmarks to be met by the end of grade divisions. There were four chapters in the *Benchmarks* that provided overtones for engineering themes, they were: the nature of science, the nature of mathematics, the nature of technology, and the common themes. In each of these chapters there were specific examples of different engineering themes, but lacked any direct correlation to engineering as they were intended to be read for the scientific community and for science education. In the first chapter, nature of science, they introduced scientific inquiry as a primary means by which to investigate science. As mentioned before in another document, the nature of scientific inquiry had a lot of overlying engineering themes within it, therefore the researcher considered this a theme in engineering. The next subsection in this chapter was scientific enterprise. This section discussed the need to consider the economic and contemporary issues that surrounded science on a global basis. The need to consider things economically was an engineering trait and theme. In the next chapter the nature of mathematics, the researcher identified three sections that would correlate to engineering themes. The first one centered on the idea of patterns and relationships, which described the need to be able to identify patterns and relationships of mathematical concepts within the natural world. Such things included numbers, angles, averages, dimensions, probabilities, ratios, cycles and correlations. These were important in the mathematical explanation of things such as our universe, galaxies, and the look at so many other things within everyday life. The second theme in this section was entitled mathematics, science, and technology. This section discussed the need to integrate science, technology, and math to be able to physically understand the role mathematics played in the deciphering of our natural world. The last section in this chapter entitled mathematical inquiry, discussed the need for us to use math as a cycle of investigation that will help lead to additional mathematical ideas, and as a result could be used in further developing engineering concepts (AAAS, 2009).

The next chapter, the nature of technology, had several key components that the researcher identified as containing engineering themes. In the first section, technology and science, they stated that tools must be used to help progress science and also use them to solve practical problems. This demonstrated a strong need to apply science in an application setting and one could consider that engineering. The next key idea came from the section designing and systems. This was the only section that explicitly talked about engineering. It discussed the fact that design was a fundamental portion of engineering and that it was used to help solve systems. Both of these were engineering themes without translation. The last section of this chapter, issues and technology, provided engineering themes on the notion that our technology would have a profound impact on the society in which it was used and that there was a responsibility to know how technology worked and to make sure that they were using it in a responsible manner. The last chapter common themes, provided for primary parts of engineering, but again were specifically utilized by the *Benchmarks* for science-specific education. The first subsection, systems, related the idea that students needed to understand systems and how they related to other key components in a closed and open system. The second subsection, models, discussed the fact that physical mathematical conceptual models were necessary tools to help decipher the natural world. The fourth subsection, consistency and change, discussed the fact that students needed to be able to consider the patterns of change that involved scale of observations and scale of analysis. The section also discussed symmetry as being a type of consistency where it could be considered a variance in the midst of change. The last section in this chapter, scales, was used to discuss that students needed to understand how to relate size, distance, and weight and other measurements as to how they could be demonstrated at different scale ratios. They also discussed the fact that scales required familiarity in a wide range of values and the ability to express these ranges to the point where they made sense at different scales (AAAS, 2009).

Themes Presented by *CCSS*

The CCSS was a very difficult document to find themes of either science or engineering relationships. The main purpose of these standards was to provide reading and writing literacy skills over those of content knowledge or application. To be able to identify specific themes within this document that related to engineering was stretching the matter, to say at the least. In analyzing this document the researcher found ideas that could relate to the idea of engineering themes, in a very broad sense without any specific relationship. The document did in fact subscribe to the idea that there was need to integrate and evaluate content, but they did so from different sources. The document also stated that students needed to delineate and evaluate an argument to a specific claim, which could be interpreted as an engineering theme but again had taken on the shape of specifications relating to reading and writing. Within the reading standards for literacy, science, and technical subjects, the researcher found three subsections that would pertain to some engineering themes. (1) In the subsection of an aggression of knowledge and ideas, the document did in fact discuss integration and evaluating multiple sources of information. (2) It also raised the question of evaluating hypothesis, data, analysis, and conclusions in a science or technical text. (3) Last, it included a portion discussing the need to synthesize information; however it again was driven toward the idea of multiple sources. It was to this extent that the researcher was able to find only trace amounts of anything relating to true engineering themes or content ideas. This document did not provide standards for science or engineering as a content driven guide, and therefore could not be used to truly indicate any form of engineering themes to be developed by students (NGA, 2010).

Themes presented by ABET

The researcher chose to analyze this document last for engineering themes for one very specific reason; it was a document on criteria for accrediting engineering programs. It was not designed to provide standards, benchmarks, or a framework for developing standards. It did however, specify what universities needed to make sure students understood in order to successfully be considered engineers upon graduation as ABET is focused on post-secondary education. They referred to these as student outcomes, and they provided 13 of them for which a university must meet in order to be classified as an ABET accredited engineering school. These 13 outcomes could be considered themes if you consider the fact that they were specifying abilities that students need to have. These themes included the ability to apply knowledge of math, science, and engineering. They needed to have the ability to design and conduct experiments and to be able to utilize and analyze the information from these experiments. Students must be able to design systems and components or processes. Students needed to have an economic, environmental, social, and ethical consideration for the needs of mankind. Engineers needed to be able to solve problems and to be able to communicate effectively (ABET, 2011).

Common Engineering Traits of the Documents

When comparing the different documents to each other, four of them showed an easy correlation and provided numerous examples of engineering themes in common. Three of those documents included the *NRC Framework*, the *NSES*, and the *AAAS Benchmarks*. All four of these documents provided themes in engineering that were listed as being the primary attributes for engineering education, as described by the National Research Council. These four documents had descriptions of engineering themes including: defining problems, models, investigating, analyzing and interpreting data, math and conceptual thinking, design, solving and evaluating solutions, and communications. And although the documents did not express them in the exact same manner, the underlying themes were there and expressed to some degree. The major differences in those four documents came from the fact that the *NRC Framework* was developed with integration of science and engineering specifically in mind. As a result the engineering themes were spelled out in the text, whereas in the *NSES* and the *AAAS Benchmarks* were written to meet science education standards, without engineering being specifically mentioned. The fourth document of accreditation criteria, written by ABET, could also be listed as sharing all the same common themes in engineering. However, these things were written with the notion of developing a set of criteria for accrediting an entire program in engineering at the university level. This document was not designed to help develop standards, but it could be used to help identify where students eventually could be in a post-secondary school system. The last document, The *CCSS*, was not written with scientific or engineering content in mind, but with the idea of reading and writing literacy competencies driving the standards. As a result the only commonality that the *CCSS* had with the other documents was a small part about analyzing data and being able to communicate it through written and read text. Table 2 outlines the traits by document and is explained in greater detail below.

Table 2
Engineering Traits in Curriculum and Standards Documents

Engineering Trait	*NRC Framework*	*NSES*	*AAAS Benchmarks*	ABET	*CCSS*
Defining Problems	Students are expected to define and understand problems.	Students are required to be able to identify a problem as noted by particular standard.	Subscribes to inquiry-based learning, which applies the notion of identifying problems.	Students must have the ability to identify engineering problems.	No such engineering trait identified in this document.
Models and Modeling	Students will develop models to use in aiding in their design.	Modeling is an assisting tool as described in designing an opportunity standard.	Located in mathematics section, it states that malls are used in common format Max inquiry and symbolic relationships.	Since are expected to have the ability to formulate engineering problems in modeling.	No such engineering trait identified in this document.
Investigating	Students need to conduct research along with designing and conducting experiments in order to help develop as many solutions as possible.	Subscribes to inquiry-based learning, which applies the notion of scientific inquiry.	In the nature of technology, students need to be able to use technology and tools to conduct research and answer their questions.	Students need to conduct research along with designing and conducting experiments in order to help develop as many solutions as possible.	No such engineering trait identified in this document.
Analyzing and Interpreting Data	Students need to eliminate and develop possible solutions from information that is quantitative.	Subscribes to inquiry-based learning, which applies the notion of some data analysis and interpretation.	Students need to be able to use math to interpret organize and find solutions.	Students need to eliminate and develop possible solutions from information that is quantitative.	The reading and writing standards require students to build, interpret, and analyze information.
Mathematical and Conceptual Thinking	Makes note that math is important and necessary to be used in helping to find solutions as noted by the developing possible solutions section.	No such engineering trait identified in this document.	Makes note that math is important and necessary to be used in helping to find solutions as noted by the mathematical world section.	Students need to eliminate and develop possible solutions from information that is quantitative.	No such engineering trait identified in this document.
Design	Since are to	Design is mentioned as	Design is discussed as an	Design is mentioned in	No such engineering

	develop possible solutions using engineering design methods which have been made in a set of design standards.	aspects of scientific inquiry, but not specifically as a standard, but used application.	integral part of technology as described in the chapter "designed world".	several different facets, and is a major criterion for accreditation.	trait identified in this document.
Argumentations for Solving and Evaluating	Students must be able to argue their points of view and the means by which they came to them.	Students are expected to be able to deliberate on the methods and the solutions by which they developed: choosing between solutions, the impact of solutions, and evaluating solutions.	Students are expected to be able to deliberate on the methods and the solutions by which they developed as noted in the issues and technology section.	Students are able to communicate their ideas and to be able to reason out the means by which they solve their problems and the methods they used.	Students are expected to be able to write out the reasoning's for their thoughts.
Communication	Students are to have the ability to communicate effectively and efficiently, as described in the influencing of engineering on society and the natural world section.	Students need to be able to dictate the problems, the processes, and the solutions as part of the mathematical world and science content standards.	No such engineering trait identified in this document.	Students must have the ability to communicate effectively.	No such engineering trait identified in this document.

Engineering Traits of Defining Problems

When looking at the documents, the researcher found that three of them possessed the common engineering theme of defining problems. These are the *NRC Framework*, *NSES* and the *AAAS Benchmarks*. In the *NRC Framework*, it states outright in the defining and delimiting engineering problems section that students were expected to define and understand problems. In the *NSES*, students are required to be able to identify a problem as noted by that particular standard. For ABET, it is a key component in the criteria as it simply stated that students must have the ability to identify engineering problems. The last two documents, *AAAS Benchmarks* and *CCSS*, they did not include this standard or anything similar. However, *AAAS Benchmarks* subscribed to the notion of inquiry-based learning, which in itself applied to the idea that a student needed to be able to identify the problem.

Engineering Traits of Models and Modeling

For models, the engineering theme was found in four of the documents. They were: the *NRC Framework*, *NSES*, *AAAS Benchmarks*, and ABET. The *NRC Framework*, again specifically stipulated in the developing possible solutions section, that students would develop models to use in aiding in their design. As for the *NSES* and *AAAS Benchmarks*, they both followed the same basic outline as they look at modeling as an assisting tool, where the *NSES* had developed theirs in designing an opportunity standard, and *AAAS Benchmarks* did so in their mathematics section, stating that models were used in common for mathematic inquiry and symbolic relationships. Again for ABET, this was an outright stipulation where students were expected to have the ability to formulate engineering problems in modeling. As in so many other engineering themes, *CCSS* was lacking in any form of engineering theme relating to models.

Engineering Traits of Investigating

Investigating was looking at the ability of students to conduct research in order to be able to help define the problem and answer it as well. Of our five documents, four of them represented this common engineering theme. The *NRC Framework* and ABET were almost word for word identical in nature. They both stipulated that students needed to conduct research along with designing and conducting experiments in order to help develop as many solutions as possible. The *AAAS Benchmarks* document also shared this engineering theme within the technology and science benchmark inside the nature of technology chapter, stating that students needed to be able to use technology and tools to conduct research and answer their questions. Once again, the *NSES* was missing this engineering theme specifically, but could be insinuated by the notion of scientific inquiry and the *CCSS* shared no attributes to suggest any engineering theme relating to investigating.

Engineering Traits of Analyzing and Interpreting Data

Of the five documents, four of them included analyzing and interpreting data as a common engineering theme. Looking at *NRC Framework* and ABET, they both specifically discussed that students needed to eliminate and develop possible solutions from information that was quantitative. Within the *AAAS Benchmarks* document, it suggested that analyzing and interpreting data was a major portion of the mathematics world chapter along with the nature of mathematics, specifying that students needed to be able to use math to interpret, organize, and find solutions of the natural world. The *CCSS* had this engineering theme in common to a minor degree, such that one of the reading and writing standards required students to build, interpret, and analyze information. As for the *NSES*, this document did not actually specify an analyzing and interpreting standard, however, one could take it to be part of the science inquiry basis of learning once again.

Engineering Traits of Mathematical and Conceptual Thinking

Because one of the major attributes of engineering is mathematical and conceptual thinking, it would stand to reason that this would be a necessary engineering theme in any engineering process. Within this theme a near mirror image may be seen for the last two themes as far as content or approximation. The *NRC Framework* along with the *AAAS Benchmarks* specify that math is important and necessary to be used in helping to find the solutions as noted by the developing possible solutions portion of the *NRC Framework* as well as the mathematical world and *AAAS Benchmarks*. The *NSES* failed to make this a priority in its science content standards, and as a result did not share this theme with the other documents as an engineering specific theme. This was related to the notion that they had a tendency to clump these ideas in with scientific inquiry, not into the standards themselves to be taught or learned within this document. As for the *CCSS*, it completely neglected the mathematical and computational thinking themes within the science standards. It did not however; suggested that within the mathematical aspects of the common core standards that mathematical thinking was in fact part of that document; however, it stressed literature literacy over content literacy.

Engineering Traits of Design

In the design engineering theme, it was considered that this was, if nothing else, the most important aspect within engineering as it was defined by the National Research Council. Therefore, it was encouraging to see that this was made very noticeable by all documents, with the exception of the *CCSS*. In the *NRC Framework*, students were to develop possible solutions using engineering design methods, which were set up in its own set of standards specifically to meet engineering design needs. The term design, used by ABET, was mentioned several times in several different manners but ultimately it was specifically identified as a major criteria for University accrediting. The AAAS document design mentioned not only in design and systems and part of the nature of technology chapter but also it had its own chapter entitled the “designed world”, which looked at different aspects of technology design for many different forms of technology. Once again, the *CCSS* shared no attributes relating to design.

Engineering Traits of Argumentations for Solving and Evaluating

The ability to provide an argument for solving and evaluating one's solutions or data is an instrumental part of the engineering process, and iss considered one of our engineering themes. Within the *NRC Framework*, this theme appeared in developing possible solutions standard and optimizing the design solution, where students must be able to argue their point of view and the means by which they came to them. This could be seen in the ABET format, where an expectation was that students were able to communicate their ideas and to be able to reason out the means by which they solved their problems and the methods they used. Within the *NSES* and AAAS documents students were also expected to be able to deliberate on the methods and solutions by which they were developed. Within the *NSES*, these themes could be found in choosing between solutions, the impact of solutions, evaluating solutions and consequences. Within *AAAS Benchmarks*, this was seen in the issues and technology, a subsection of the nature of technology. This theme had a minor relevance within the *CCSS*, as students were expected to be able to write out their reasoning for their thoughts; however, this was not a direct engineering theme as it was written.

Engineering Traits of Communication

The last theme, communication, was expressed in all but one of the documents this time. This trait was missing from *AAAS Benchmarks*, but seeing as this document also appealed to the notion of inquiry-based learning, it could be interpreted from the idea that students needed to be able to share their findings. As for the *NRC Framework* and

ABET, this was specifically identified as the ability to communicate efficiently and effectively. In the *NRC Framework*, it was found in the influencing of engineering on society and the natural world, a subsection of the engineering core disciplinary ideas. In ABET, this was the last criteria in their list, and it simply stated students must have the ability to communicate effectively. Within the *NSES* document, it stipulated that students needed be able to communicate the problem, the process, and the solutions as part of the mathematical world and science content standards for technology. Once again stretching the term for the theme in engineering by the *CCSS*, because this document was so heavily laden on the reading and writing aspects of science literacy, it stood to reason that communications was a primary attribute of these standards.

The Past, Present and Future of Engineering Education

To understand the future of the papers, the researcher first wanted to look at the past and the purpose of the papers. If examined in chronological order, it was evident one paper led to another and to another and so on. In this chronological nature the first one that was considered the *AAAS Benchmarks*. The *Benchmarks* were developed as a result of Project 2061, a project that was to restructure science education for the future. The *Benchmarks* were developed from the Project 2061s Science for All Americans publication of 1989 (AAAS, 2009). This document laid out the foundation for what was to become standards in K-12 education. When they developed the *Benchmarks* they decided that these were not to actually be standards, but a foundation or framework for helping to develop science curriculum across the country and to help bring in a new era of science education. The *Benchmarks* were published in 1993 and have since been updated as late as 2009 (AAAS, 2009). The general framework of the *Benchmarks* had not changed at all, but was used to help in the development of several papers since then by the American Association for the Advancement of Science, including the *Blueprints for Reform*, a document to help reform curriculum in science, mathematics, and technology to be used throughout the entire education system. However, in 1995 the National Research Council decided to take on their own science education initiative. The National Academy of Sciences, along with several other independent organizations in 1996 developed the *NSES* which were currently being used nationwide to help develop state standards in science education (NRC, 1996).

Currently, the *NSES* is on its way to being replaced by the *NRC Framework*, as developed by the National Research Council, and the *NGSS*, as developed by Achieve. The primary goal for replacing the *NSES* was to re-examine the way we approached science education, and to be able to incorporate engineering themes into the next generation of science standards (NRC, 2011). Achieve, the organization charged with development of the *NGSS*, put forth a set of standards that would be taken to the states to be used, or incorporated in their own standards for science education. The previous two documents, the *Benchmarks* and an *NSES*, were not slated to specifically foster engineering education in the K-12 setting. This was one of the major goals of the *NGSS*, fostering a new era of science education that incorporated engineering in science curriculum and the standards that would be developed around them (NRC, 2011). When looking at The *CCSS*, currently the standards had no intent of incorporating engineering themes or content into the literacy standards. However, it was important to note that the common core standards were not content-based standards. These standards were developed to support the language arts within science and technology, not the application or content knowledge thereof (NGA & CCSSO, 2010). Therefore, it would be inappropriate to state that there was a future application of the common core standards in engineering at this time. This was not to say that there was no potential for it, it was simply not being conceived in the foreseeable future. The ABET accreditation criteria was ever-changing and there was discussion about producing K-12 education standards from ABET to be used in helping to guide and design future engineering curriculum in the primary school system. Currently, ABET has already stated that they felt there were enough engineering themes within current science curriculas that a separate curriculum would not be advantageous at this time (ABET, 2011).

The *NRC Framework* Verses the *NSES*

When comparing the *NRC Framework* to the *NSES*, they both shared many primary engineering themes. However, the *NRC Framework* picked up at a major turning point that the *NSES* left behind. This major turn came from the fact that the *NRC Framework* designed specific standards for engineering including specifically creating standards dealing with engineering design, as opposed to basic design which could be found in the *NSES* standards (NRC, 2011). As for the specific terms that were missing from the *NSES* there were three of them, they included: investigating, analyzing and interpreting data, mathematical and conceptual thinking. However, as mentioned before, the *NSES* gave light to these themes in terms of the inquiry-learning strategies as prescribed by the *NSES*. Some specific core ideas from the *NRC Framework* included; defining and delimiting an engineering problem, developing possible solutions, and optimizing the design solution. It was the specific terms and goals that separated the *NRC Framework* from the *NSES*.   Another major step forward for the *NRC Framework* was the adoption of crosscutting concepts, which was the idea of incorporating the different sciences along with engineering into the standards. These crosscutting concepts carried engineering themes that were not in the *NSES*. These themes included finding, observing, and understanding patterns, investigating the mechanism and explanation from cause-and-effect, using and incorporating scales, proportions and quantities, utilizing and developing systems and system models, being able to track and understand the flows, cycles, and conservation of energy and matter in systems, the structure and functions of objects and systems, and stability and change of systems. These were the major themes and stepping stones in the *NRC Framework* that were developed to take a new stance on science, and hence the new phrase of practicing science and not simply inquiring about it. This theme of practicing was definitely inherent to the idea of engineering; we never say, "I do engineering," but that "we practice engineering." Although this seemed like a simple notion or idea, it was a major step forward in the incorporation of engineering into the science education field. This was the major difference between the *NRC Framework* and the *NSES* (NRC, 2011).

Material and Program Evaluation Frameworks

Introduction to Material and Program Evaluations

A search was conducted through ERIC and Google scholar to locate materials on material evaluation as well was program evaluation. The researcher was intrigued to find that a very limited amount of material published on the evaluation of educational materials; however, the researcher was able to locate many more sources on program and assessment evaluations. From the search the researcher found two primary frameworks that were considered for further research and reading. The Technical Education

Curriculum Assessment produced by the Advanced Technology Education project and measuring fidelity of implementation as it related to K-12 curriculum. As the researcher will discuss further, the researcher found both of these two frameworks to be of practical use for answering the research questions along with the development of the instrument that was used in evaluating Earth science materials available to teachers on the internet. The researcher found the Advanced Technology Education project's Technical Education Curriculum Assessment tool to provide the foundation that was used in instrumentation development. Other materials that were reviewed but were rejected, included evaluation of assessments, and consequently the researcher did not find it to be of practical use in the research. Further discussion of the instrument, along with the sampling will be discussed further and in greater detail in the method chapter.

Advanced Technology Education (ATE) and Technical Education Curriculum Assessment (TECA) Framework

One of the curriculum evaluation models used today was the Technical Education Curriculum Assessment (TECA) rubric. The TECA was originally designed as "a set of rubrics to assess workplace competencies, technical accuracy, and that pedagogical soundness (Keiser, Lawrenz & Appleton, 2004, p. 181)" of technical education curricula. This was an evaluation tool used initially to look at and assess technical and vocational education literature and curriculum material. However, today this evaluation tool was used in assessment of curriculum materials in: science, engineering and technology (Keiser, Lawrenz & Appleton, 2004). The researcher considered this a hardware evaluation toolkit, for evaluating and applying this assessment tool toward materials and not teaching techniques, or teaching pedagogies as they applied to the instructors or the students directly. This was technique used in evaluating worksheets, Power Points, textbooks and other related materials used in curriculum and teaching (Yarnall, 2010). As a result, the use of the TECA had grown from simply being a technical curriculum tool, to being used in multiple disciplines and across different grades and schools (Keiser, Lawrenz & Appleton, 2004). In 2009, California used the TECA to evaluate programs all over the state, but predominantly in the prison systems in the areas of technology and engineering in order to evaluate their strengths, weaknesses, and other areas of interest for each individual program (State of CA, 2009). The TECA was used in multiple settings across multiple states to evaluate an array of different curriculums without having to reinvent the wheel for each evaluation. The TECA curriculum evaluation rubric was designed to be used as an assessment tool in science, technology, engineering and math (STEM) fields (Keiser, Lawrenz & Appleton, 2004). Throughout the evolution of the TECA curriculum evaluation tool, there were modifications made to it, that transformed it from a quantitative tool, to mix methods, and more recently used as a qualitative assessment tool. This developed as researchers wanted more open-ended questions and leaving the Likert scale system that was initially in place in the development of the rubrics system. Such examples existed in the Massachusetts science and engineering curriculum framework.

History of the TECA. The TECA was developed from the Advanced Technology Education (ATE) program that was commissioned by the National Science Foundation (NSF) in 1999 and the program responsibility was given to the Evaluation Center at Western Michigan University (Lawrenz & Appleton, 2004). The original premise of this program was to guide technical education in instruction, student engagement, assessment, and curriculum development. However, the strategies used in the development of this evaluation tool were also suitable for any other disciplines. The ATE was designed to enlighten programs in science technology and engineering along with the ability to assess and develop better uses and methods for instruction, learning and engagement. From this study, several different applications were developed, and amongst them were a few curriculum assessment tools (Keiser, Lawrenz & Appleton, 2004). In examining the tools that were produced from this program, the researcher selected the TECA for its malleability and assessment ability towards multiple disciplines in multiple settings. Since its development in 2004, the TECA was used in multiple studies in varying subjects (Yarnall, 2010). Such constant and progressive use of this evaluation tool went to the credibility, validity and even reliability of the instrument to provide accurate information, across multiple disciplines and settings. Some of the most current and modern uses of the TECA instrument were used in the development of new curriculum to meet upcoming standards, as well as to stay ahead of developing standards and state requirements. Furthermore, the TECA instrument seemed to have become a standard within the NSF ATE and programs associated with that grant as noted by the number of times that was referenced in ATE research projects (Greenseid, Johnson & Lawrenz, 2008).

Theory of the TECA. The TECA was developed looking at several different aspects of what a person would need in the workforce to be competent and what was portrayed as a successful technical education. When looking at the competencies needed for workers by industry, the Secretary's Commission on Achieving Necessary Skills identified several competencies necessary to fulfill these requirements for the workers in the workplace. These competencies were identified as: resources, information, interpersonal skills, systems, and technology. To help identify what constituted successful technical education curricula, the researchers turned to Finch and Crunkilton, who stated that the curriculum needed a processes and a product. They mentioned that curriculum must be motivated pedagogically and by the industry. The Curriculum development in vocational and technical Education: Planning, content, and implementation by Finch & Crunkilton (1999) listed several factors that they believed were necessary to maintain highly relevant curricula in order to meet the needs of the working world. These factors included: data based, dynamic, explicit outcomes, fully articulated, realistic, student oriented, evaluation conscious, future oriented, and world-class focused (Finch & Crunkilton, 1999). The last research that was taken into account while developing this method of curriculum evaluation was done by Wiggins and McTighe who pointed out that students should be able to follow six aspects of understanding: explanation, interpretation, application, having perspective, empathy, and self-knowledge. After deliberating on these three different research dynamics, they determined that there were three major themes needed to support their rubrics: responsive educational experiences, deep understanding, and relationship to work (Wiggins & McTighe, 1998).

The major intent of the rubrics was to allow the evaluators an opportunity to evaluate curriculum material as related to their own professional experience or what was considered needed by them to progress within their own professional abilities. This was a multifaceted evaluation system that relied on multiple professional viewpoints to come to consensus as to the results of the curriculum evaluations. It was from these multiple viewpoints of the same material that the results would be considered by what was found in common from each of the evaluations and used to rate the materials, or provide feedback about the materials. It was the job of the program investigator to interpret the feedback from the difference evaluations and to provide a consensus as to the results that will lead to these determinations.

The TECA Instrument. TECA was comprised of a series of rubrics that were completed by three primary groups of people. The first sets of people were presenters, the second groups were the observers, and the third groups were the participants. The rubrics did not need to be filled out specifically by all three groups, as they were designed to be looked at in individual categories. The rubrics were set up in a three tier system, where the first tier was split into specific professional groups as mentioned above. The second and third tier rubrics were meant to be answered by all individuals regardless of specialty. Each evaluator was responsible for completing three evaluations. The first evaluation was separated to a person's specialty and the last two were evaluations were universal in nature as everyone completed the same evaluations. Once the evaluations were completed, they were given to the program investigator for final evaluation to determine the results. (Keiser, Lawrenz & Appleton, 2004)

The first evaluation, which was specifically designed for the person completing it (i.e. participant, observer, facilitator) as it related to the materials that were used. The evaluators were basing their information from industry and instructional aspects of quality, dichotomous grading questions, and evidence that was necessary to explain their rating of the material. The second aspect of the evaluation was a holistic rating assessment. In this, everyone involved in the evaluation system answered the assessment.

Within this assessment, evaluators were asked to consider the integration of both standards and pedagogy, again they were asked to explain the reasoning for their ratings. Within the last evaluation, everyone answered a simple, single question. This question asked them to give their overall opinion of the curriculum material that they were asked to evaluate. They were asked to explain their answer. From this set of evaluations, the program evaluator would come up with a consensus for the answers and explanations that were provided by all the individual evaluations. Because this was a mixed method assessment, there may be much room for interpretation as provided by each of the evaluators. To assist with the reliability of the information provided, there were "yes" and "no" questions provided on the first two evaluations to help provide a baseline for some basic identifying questions.

Validity and reliability of the TECA. Validity for the individual and the group forms came in part from a publication by Keiser, Lawrence and Appleton titled *Technical Education Curriculum Assessment* (2004), it was determined that the TECA had a very high reliability and validity. The TECA was used and documented in 96 different studies on the basis of material evaluations (Greenseid, Johnson & Lawrenz, 2008). In the development of the TECA, an effort was made to make sure that the validity of the instrument was proven. This was accomplished by having the rubric, also known as the instrument, validated by 60 expert reviewers that were selected amongst the Advanced Technology Education program. Of the 60 expert reviewers, 18 of them were invited back for a meeting to discuss, review and revise the rubric (Keiser, Lawrenz & Appleton, 2004). In an effort to provide reliability, the rubric once finalized by the experts, was used with four separate items that were to be evaluated by the expert panel to determine reliability. On average, 90% of the time the panel was in an agreement within one point and 50% of the time, they were in perfect agreement. A correlation of 0.77 was determined in the results. It was by these reviews of the expert panel in developing the rubric and utilizing it, that the instrument was deemed to be both valid and reliable (Keiser, Lawrenz & Appleton, 2004).

Measuring Fidelity of Implementation and its Relationship to K-12 Curriculum

This was a new and different look at evaluating the effectiveness of K-12 curriculum interventions, described as the fidelity of implementation. "Fidelity of implementation was traditionally defined as the determination of how well an intervention is being implemented in comparison with the original program design during an efficiency and/or effectiveness study (O'Donnell, 2008, p. 33)." So this was a means by which to study how closely to the design the intervention was being implemented. Research into the fidelity of implementation was rare at best in K-12 education and curriculum. Most of the research came from public health literature as this was discussed since the 70s. According to public health literature, there were five criteria for measuring fidelity of implementation. They were: adherence, duration, quality of delivery, participant responsiveness, and program differentiation, with each of the criteria adhering to some critical nature of the evaluation system (Hall & Loucks, 1977). (1) The first one, adherence, asked whether or not the program was being implemented as designed. (2) The second one, duration, was reflective of the number, length, and frequency of the sessions implemented. (3) The third one, quality of delivery, looked at the techniques, processes, and methods being used to communicate or implement the program. (4) The fourth one, participant responsiveness, looked at the extent of engagement by the participants that were involved in the activities. (5) The fifth and last one, program differentiation, looks at whether or not important features allowed a comparison in the condition or precedence during the implementation. The use of fidelity research was important in an age where the need for education accountability was on the rise, as this shows whether or not an intervention or implementation is being effective. Today the widest use of evaluating “fidelity of implementation” as it related to K-12 education was in the effectiveness of instruction by teachers as well as educational material. Furthermore, there were recent developments in the use of this model to help identify strengths and weaknesses and instructions for students with disabilities and other minority situated cases (Gersten, Chard, Jayanthi, Baker & Morphy, 2009). The idea of measuring fidelity in K-12 education was not new to the field in general, but developed as a more specific research over the past several years.

History behind fidelity. The whole idea of measuring fidelity came about in the early 1970s to examine the healthcare profession and its ability to maintain and provide professional development for healthcare professionals. It was an overwhelming question as to how effective it was in transmitting new ideas and techniques to those who had to implement these new ideas in hospitals and other healthcare related professions. In the late 1970s, the idea of using fidelity of implementation started to be recognized in the education setting when very early research was done to look at different aspects of fidelity in K-12 education. And although most of this research was done to evaluate the process of the curriculum, it has grown since then to evaluate instruction as well. Up until O’Donnell’s research in 2008, there was very little if any research done on the evaluation of fidelity and how it is been approached in the education setting. For the most part we still looked at fidelity, although we actually thought of it more as the evaluation of curriculum effectiveness and instruction, it was still considered an important part of research in education today (O'Donnell, 2008).

Theory of fidelity. In the education community, there is a dilemma with regard to evaluating and measuring fidelity in education. Since the notion of fidelity was the ability to implement an intervention in the success by which was done, we could think of that in the education realm as being curriculum implementation. The issues with fidelity in curriculum implementation come from the notion that there were conflicting ideas about fidelity and adaptation. Within the education community, adaptation was considered an essential part of curriculum. This was contrary to the idea of fidelity, in that one was deviating from a prescribed intervention and therefore lost some of the procedures that were developed in the implementation of these interventions.

In discussing the application in the ability of applying fidelity of implementation to K-12 curriculum intervention research, six points should be considered. The first point was that fidelity of implementation was lacking in K-12 curriculum intervention research and as such, curriculum intervention researchers needed to implement a framework for studying the fidelity of implementation. In the second point, there needed to be a distinction made between measuring the fidelity to the structure components of curriculum intervention and the process that guided its design. It was important to understand that processed criteria may be more difficult to measure and may also be more significant in the program's effects. It was important for researchers to measure fidelity in both structure and process of an intervention and to be able to relate it to the outcomes. The third point, it was important to understand that the whole school model was different than individual teachers' model when it came to the curriculum reform and the fidelity of implementation. To evaluate the fidelity of implementation of an entire school wide system was far more complex than that of an individual teacher. One of the biggest challenges to look at the fidelity of implementation to a school wide system was the unknown factor of how teachers may adapt materials or routines to suit their particular needs in their classrooms. The fourth point discussed the differences in measuring fidelity of implementation. Critical components to the processes when looking at fidelity should be captured quantitatively as much as possible and outcomes could be adjusted accordingly should they fall outside an acceptable range. The fifth point was regarding adaptation in the fidelity of implementation when considering the constructs in the fact that they should be measured separately as they related to the outcomes. The last point discussed a set of guidelines that must be established to be able to better measure fidelity of implementation with regard to K-12 curriculum intervention (Mills & Ragan, 2000).

Instruments to measure fidelity. In the K-12 setting, fidelity of implementation can be measured by looking at curriculum interventions that include training programs or professional developments. Measuring fidelity of implementation involved looking at observable variables and included components that met the needs of the study and then using the collected data to correlate the given results. Evaluating fidelity of implementation or evaluating the effectiveness of curriculum instruction was a quantitative tool as a consequence of correlating data from appropriate Likert scales. To start, one would look at a set of fidelity criteria in order to figure out what components of the intervention were necessary to be able to conduct the study. The following have been laid out as a five-step checklist for a process of creating the components. The checklist was as follows: “identify the innovation components (participant activities, behaviors of the implementers, materials) by reviewing the program materials and consulting the program developer; identify additional components and variations by interviewing past implementers to ascertain ideal use and unacceptable use for each component; refine the program components by going back to the developer and clarifying with him or her user discrepancies regarding which of the observed components is the most important; finalize the innovation components by constructing a component checklist and a set of variations within each before piloting; and collect data either in written, classroom observation, or by oral interview.“(O’Donnell, 2008, p. 49) The methods used to collect data varied greatly from self-report surveys and interviews to analysis of materials, observations, questionnaires, and video. “By examining and measuring fidelity criteria using multi-methods in relating these measures to student outcomes, researchers can differentiate between implementation failure and program failure.” (O’Donnell, 2008, p. 50)

In the most basic of senses, the measuring the fidelity for implementation involved a series of observations, surveys and interviews. These are done in a fashion that involves many different participants as one looks at the implementation of an intervention by many individuals. In essence, the program investigator observes several different participants involved in the professional development that received the intervention training. The participants are also asked to fill out a series of surveys evaluating their sense of effectiveness from the training. Data are gathered in the form of surveys, and these observations then turned into qualitative data which could be analyzed for further analysis. This information provides the results for this study. The results of this study in turn pave the way to an understanding of whether or not the training for the intervention was successful or the implementation of the intervention was successful. Furthermore, this information can also be useful for development of future implementations or for making any modifications to the set of participants involved in the intervention itself (Mills & Ragan, 2000).

Material Evaluation Summary

As described and discussed, fidelity provided an opportunity to look at an intervention at work, which could be the basis for further study in the future as a result of new curriculum being developed. Using the TECA framework allows the researcher an opportunity to evaluate materials as they currently exist, such that they may be able to improve upon them for future use with regard to the new *NRC Framework*. The researcher also holds that this work will provide an additional source for future material evaluation in other fields and help to strengthen a new line of research in the evaluation of teaching materials.

Chapter 3

METHODOLOGY

Introduction

This was a mixed methods study that incorporated a survey and grounded theory analysis to answer the research questions: (1) To what extent were the crosscutting concepts of the *NRC Framework* present in Earth science teacher materials available on the internet? (2) To what extent were the engineering crosscutting concepts of the *NRC Framework* present in Earth science teacher materials available on the internet? and (3) What themes were present in the Earth science teacher materials available on the internet?

The analysis was completed by two evaluation techniques: a Likert-scale content survey, and basic grounded theory. Using these two techniques provided a mixed methods approach to evaluate the data, providing different approaches to examining the material. The data collected from this study have the potential to provide a base for further studies as it could show a need to evaluate other programs for the *NGSS* and the engineering and science cross-cutting concepts that will be required along with it. Furthermore, as *NGSS* includes engineering concepts, the first ever, there exists a need for evaluating teacher materials for these concepts (NRC, 2011). Everything from material available on the internet to textbooks depends on such studies to help ensure they meet the future requirements of the *NGSS*.

This chapter is subdivided into four primary components, consisting of: the sample, the instrument, the analysis process, and last reliability and validity. Each section described the components used in the methodology that was incorporated into the study.

In the sample section, it was discussed as to the means by which sample items were obtained, along with the sources of the sample items. The instrument section discusses both the material evaluation rubric and a brief overview of grounded theory that was also used. Within the overview of the material evaluation rubric, a discussion was made as to its background, development and finally the resulting instrument. The analysis process section includes a discussion as to the means by which the analysis was performed in the study. This section also includes a flowchart, to help describe the process visually. In the last section, the validity and reliability of the instrument and the analysis was described and discussed. The results of the analysis is described in Chapter 4, and further discussed in Chapter 5.

Sample

The study looked at material used and distributed to teachers in K-12 Earth science, and specifically earthquakes, from EarthScope (http://www.earthscope.org) research projects along with other materials found on the internet. Materials were identified both through the National Science Foundation’s list of grant projects that related to the national EarthScope Program, and materials that were found on the internet using Google. To determine whether or not materials were suitable for evaluation, they were checked against these requirements: suitable material contained lesson plans, instructional strategies, or students’ activities that would be used by teachers and related to earthquake science.

Given the scope of the research questions, it was unrealistic to look at all aspects of Earth science. As a result this study considered only teacher materials that related to earthquakes in Earth science. This allowed a more reasonable research study to be performed given the limited time and resources available to complete this particular study. If in the future, more time and resources become available, it would be possible for a more in depth study to be performed that would be more inclusive of different aspects of Earth science. This study provided a sampling of one specific aspect of Earth science, with the potential to evaluate and research other materials not only in Earth science, but other science disciplines as well. Materials that were used in this research study came from two primary sources. The first source came from a search of EarthScope in the National Science Foundation website under active grants. The second source, came from a Google search of the Internet for earthquake teacher materials.

NSF EarthScope Grant Search

A search of the National Science Foundation grant awards using the keyword "EarthScope" produced 141 results. After eliminating duplicate contacts, the list was reduced down to 119. From the 119, four additional contacts were removed from Arizona State University, as these programs do not participate in K-12 education and outreach. A recruitment email was sent out to 115 contacts with regard to acquiring materials that were used in K-12 education outreach programs should they be involved in such programs. Within two weeks of sending out the recruitment emails, 25 responses had been received. Of the 25, three of the responses provided usable materials, 15 stated that they did not do work with K-12 education, and 7 stated they were in the process of developing content and would respond in the future. Ninety of the programs contacted failed to respond in any way.

After 30 days from the initial recruitment email, a reminder email was sent to the 90 contacts that did not reply the first time. Of the 90 reminders that were sent out, the following results were recorded: two responses provided materials, three responders indicated they would have material sometime in the future and would send them upon completion, 28 responded with having no K-12 materials or any intentions of producing them and 57 never responded with any indication.

To summarize the EarthScope recruiting process, the following represented all of the responses gathered from both the initial and the secondary request for information. From the total of 115 recruitment contacts, five responded with materials freely available on the internet, 10 stated they were working on materials, 43 responded with having no materials and 57 never responded. From those that stated they were working on materials, grants were been approved and operating since 2004 and up to 2012. This could represent a lack of motivation or insufficient resources by some of the projects to instigate K-12 education and outreach as they had yet to produce any materials at this point. For projects that started more recently, it was reasonable to assume that they had simply not been able to acquire or produce a feasible K-12 education and outreach system. The resulting efforts produced a total of 13 items of material that met the selection criteria to be used in the evaluation from the NFS EarthScope grant search. Table 3 provides an overview of the results from the EarthScope recruitment process.

Table 3
EarthScope Recruitment Summary

	Provided Materials	Working on Materials	No materials	No Response
First Request	3	7	15	90
Second Request	2	3	28	57
Request Total	5	10	43	57

Google Internet Search

In determining the NSF EarthScope grant search did not produce the desired amount of material items, an attempt was made to increase the sample size by looking at a secondary source. The secondary source was an Internet search using the Google search engine, searching on the keywords ”earthquake teacher materials” and “earthquake lesson plans”. The search yielded over 50,000 possible results, representing the maximum possible number that can be furnished by Google. From over 300 results, 32 items were found that met the initial criteria for the evaluation process. With the additional 32 items that were found using Google on the Internet, a total sample size of 45 material items was obtained.

Sample Summary

In all, 13 items were obtained from the search of active National Science Foundation grant projects, plus an additional 32 material items from the Internet Google search for a total of 45 material items, which accounted for 11% of the total lessons considered. Table 4 is a summary of the quantity of items found by each of the recruitment strategies .

Table 4
Quantity of Items by Recruitment Strategy

	NSF Grants: First Request	NSF Grants: Second Request	Google Search	Total
Quantity	8	5	32	45

The 45 items were then subsequently broken into five subcategories. The five subcategories, included: commercial organizations, nonprofit organizations, government organizations or agencies, professional organizations and university groups. Government organizations, professional organizations, and university groups all provided materials free of charge and were available on the Internet. Nonprofit organizations were groups that had no affiliation to a specific university research project or any other government, commercial or professional organization and also provided materials free of charge on the Internet. Commercial organizations included those that were for-profit but provided the materials free of charge. Professional organizations included those of the geological professional nature. The use of subcategories was used to help identify any trends that might have existed amongst the individual organizations and groups. The results were discussed in chapters four and five in greater length and detail. Table 5, shows a breakdown of the number of material items for each of the subcategories. The use of this information was discussed in more detail in the analysis section of this chapter.

Table 5
Quantity of Items by Organization Grouping

	Commercial Organization	Non-Profit Organization	Government Organization	Professional Organization	University Organization	Total
Quantity	7	15	7	4	12	45

Instrument

The study was performed using a mixed methods approach, and in doing so, two instrument types were used. For the study, a material evaluation rubric was designed and developed for the analysis of the materials. Grounded theory was also used as one of the instruments during the study; both of the tools were used concurrently in this study. Additionally, the use of Microsoft Excel and SPSS analytical software programs were used as analysis tools in the development of the results.

For the study, use of a mixed methods study was more applicable to what was being examined, as most of the data were interpreted from opinions as to the content of the material to meet the needs of answering the dissertation questions. A future study could incorporate more quantitative information and provide more statistical analysis in these future results. The researcher would suggest this type of the study as a follow-up to the research, to further explore the results that had obtained through qualitative research.

Material Evaluation Rubric

The dissertation questions revolved around looking at the materials used by teachers and students to determine the extent by which engineering crosscutting concepts were incorporated into Earth science earthquake materials. The TECA framework proved to be useful. As the research was conducted, the dissertation questions were also refined, and as such the study looked at the material available to teachers and students online. The problem with the fidelity option was that the model was geared toward the implementation of the material as opposed to what the material itself offered. This tended to be more of an aftereffect of an intervention, as opposed to the process of training for the intervention, whereas the TECA framework was geared specifically at curriculum material. This method supported a mixed method approach to the data collected and the analysis. Data collection was also based on single pieces of material, as opposed to the study of multiple interventions at multiple locations.

The material evaluation rubric was designed after the framework of the TECA, developing a series of questions to evaluate materials for content, specifically situated for the engineering crosscutting concepts of the *NRC Framework* and ultimately the *NGSS* as they related to the crosscutting concepts as well as the engineering crosscutting concepts.

The material evaluation rubric used in assessing the materials was comprised of a series of five point Likert questions, accompanied by a free response justification question and a yes-no question. For each of the seven crosscutting concepts, there were three Likert, yes-no questions and free response questions. There was one additional yes-no question asking if the material was grade appropriate, and a free response question for justification. In all, there were 22 free response questions, 22 yes or no questions and 21 Likert scale questions in the rubric, for a grand total of 65 questions per rubric. The Likert scale ranged from 1, representing not present at all; to 5, indicating that the item was consistently present throughout the entire material. The yes-no questions, addressed whether or not the item had any presence in the document, indicate whether or not it was necessary to proceed to the Likert questions and the free response justification question.

The rubric was broken up into the seven primary categories for each of the crosscutting concepts. For each of the crosscutting concepts, there were four subcategory questions. For each of the subcategory questions, there existed the yes-no question, the Likert scale question, and the free response justification question. The subcategory questions were nearly identical for each of the crosscutting concepts, with only the crosscutting concept changed in each of the subcategories.

An example of one of the crosscutting concept sections was the first crosscutting concept of patterns to demonstrate the set-up of the rubric as it would be identical for each proceeding crosscutting concept. The first of the four subcategories asked the yes-no question of whether or not there was evidence of the *NRC Framework* crosscutting concept in the document. The Likert scale question asked to what extent the crosscutting concepts are present in the document. The free response question asked for a justification for the given response. The second subcategory yes-no question, asked if there was evidence of the *NRC Framework* engineering crosscutting concepts in the document. Followed by the Likert question, as to what extent the engineering crosscutting concepts were present in the document and the free response question for justification. The third subcategory yes-no question asked, were there evidence of application of the *NRC Framework* engineering crosscutting concepts in the document. The Likert scale question asked to what extent there was application of the *NRC Framework* engineering crosscutting concepts in the document and the free response question asking for justification.

Table 6 is an outline of the material evaluation instrument used in the evaluation of the samples. The evaluation rubric can be found in the appendix.

Table 6
Material Evaluation Instrument Outline

1. Patterns
    A. Crosscutting Concepts
    B. Engineering Crosscutting Concepts
    C. Application of the Engineering Crosscutting Concept
2. Couse and Effect
    A. Crosscutting Concepts
    B. Engineering Crosscutting Concepts
    C. Application of the Engineering Crosscutting Concept
3. Scale, Proportion and Quantity
    A. Crosscutting Concepts
    B. Engineering Crosscutting Concepts
    C. Application of the Engineering Crosscutting Concept
4. Systems and Systems Models
    A. Crosscutting Concepts
    B. Engineering Crosscutting Concepts
    C. Application of the Engineering Crosscutting Concept
5. Energy and Matter
    A. Crosscutting Concepts
    B. Engineering Crosscutting Concepts
    C. Application of the Engineering Crosscutting Concept
6. Structure and Function
    A. Crosscutting Concepts
    B. Engineering Crosscutting Concepts
    C. Application of the Engineering Crosscutting Concept
7. Stability and Change
    A. Crosscutting Concepts
    B. Engineering Crosscutting Concepts
    C. Application of the Engineering Crosscutting Concept
8. Grade Appropriate

Grounded Theory

Although grounded theory is not a physical instrument, it does represent a method by which data can be collected, categorized and analyzed. References for the use of grounded theory date back to the 1920's; however, grounded theory method was officially published in 1967 (Robrecht, 1995). More recently, a greater emphasis was expressed in its use especially amongst the health care professions and educational research, with other fields finding methods and means by which to use grounded theory (Strauss & Corbin, 1994). There were many sources on the uses and the methodology of grounded theory and research; however, they all had several basic commonalities. One of the primary components of grounded theory was that there was no initial expectation of the results, that the results were identified from the data. It was this idea of developing a theory from the data that set this research approach different from research methods. Once a theory was developed from the data, research was then done to help exemplify or identify rationale behind the theory (Robrecht, 1995). Furthermore, commonly agreed-upon, were the general stages in which grounded theory was conducted. The general stages of grounded theory included: data collecting, coding, sorting, and result writing (Stern, 1980). In this study, the general stages were used in conjunction with the quantitative analysis. Grounded theory used the notion of developing trends and other common traits amongst data, in order to develop and substantiate results. Data could be anything from observations, surveys, interviews, traditional and nontraditional sources (Robrecht, 1995).

In this study, data collecting was accomplished through results of the rubric, which included both the Likert scale results as well as the open ended questions that were used in justification. Once the rubrics were collected, they were then transcribed into Excel. The coding was accomplished from analysis of both Likert scale questions along with the justification questions. Once the specific codes were identified, they were sorted and analyzed for their common themes and other similarities. The analysis section will discuss more of the process by which these steps were taken, and the results and discussion chapters will elaborate on the findings. In terms of grounded theory, this study went through three rotations of coding and evaluation of trends and themes. As described above: level I coding involved data loading and transcribing; level II coding involved organizational breakdown; and level III coding involved identification of themes and results. This information was further discussed in the analysis section of this chapter.

Analysis

The process for conducting analysis on the study used mixed methods, comprising a rubric evaluation of the materials, and the use of grounded theory to answer the research questions: (1) to what extent are the crosscutting concepts of the *NRC Framework* present in Earth science teacher materials available on the internet? (2) To what extent are engineering applications of the crosscutting concepts of the *NRC Framework* present in Earth science teacher materials available on the internet? and (3) What themes were present in the Earth science teacher materials available on the internet? By using grounded theory, the process was not so much linear as it was circular in nature. As such, the results of one section lead to questions to be answered about another section and so forth. The idea of having multilayered coating systems allowed the researcher to examine the study in an effort to narrow down ideas, concepts, and eventually the results. The general framework used here, included three levels of coding as well as three stages of numerical analytical processing.

Each stage or level of coding was accompanied by two separate stages of numerical processing using both Microsoft Excel and SPSS analytical software programs. This combination of qualitative and quantitative analysis that allowed the researcher to examine the materials for not only basic statistical properties, but for trends that exist in a qualitative sense. This study included three levels of coding, which also included three levels of statistical and descriptive analysis. In each of the levels, Microsoft Excel was used to conduct descriptive analysis, finding the mean and standard deviation of the Likert question results. Figure 1, provided a flow chart demonstrating the basic process as to the means by which the analysis was conducted.

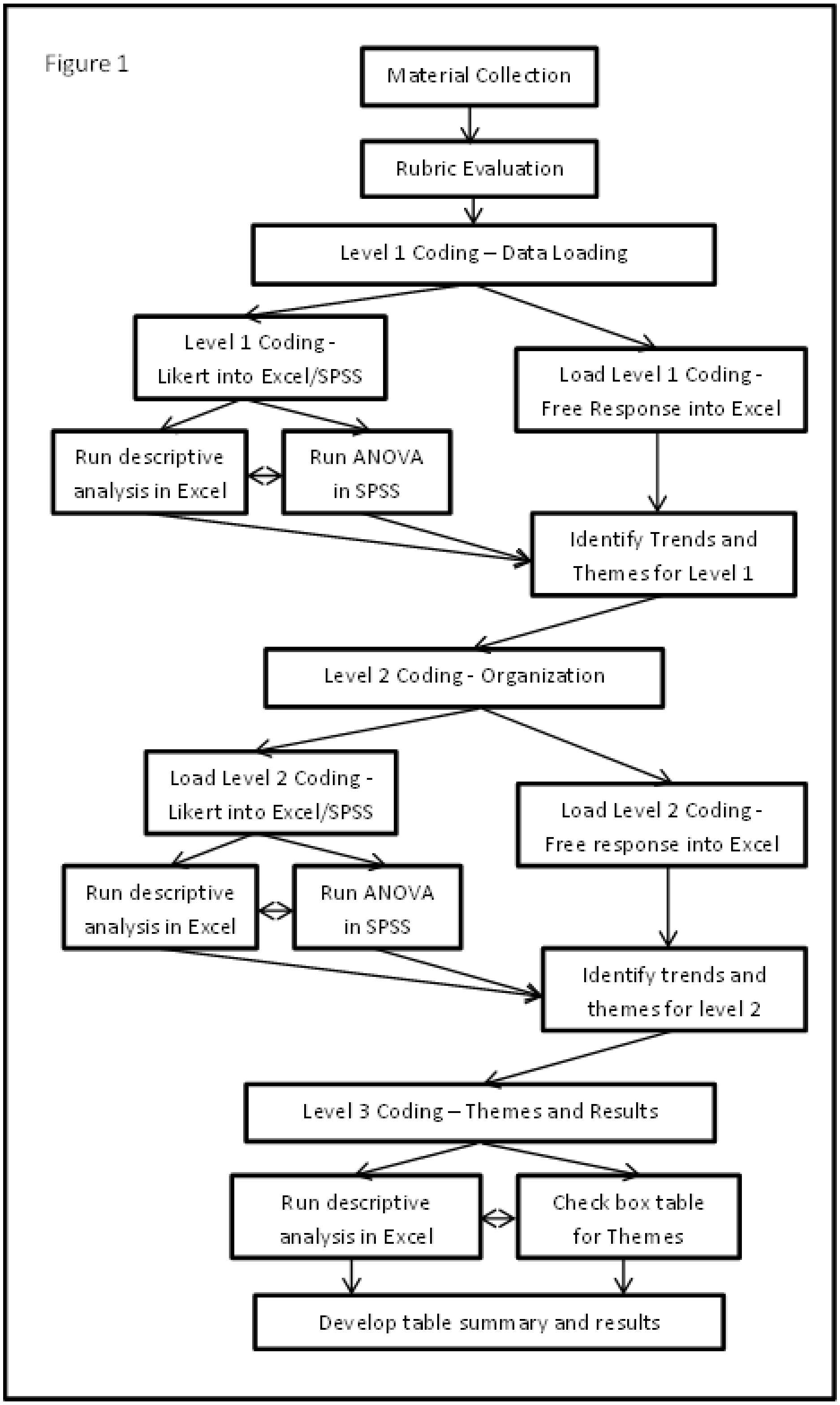
Figure 1
Material Collection
Rubric Evaluation
Level 1 Coding – Data Loading
Level 1 Coding - Likert into Excel/SPSS
Load Level 1 Coding - Free Response into Excel
Run descriptive analysis in Excel
Run ANOVA in SPSS
Identify Trends and Themes for Level 1
Level 2 Coding - Organization
Load Level 2 Coding - Likert into Excel/SPSS
Load Level 2 Coding - Free response into Excel
Run descriptive analysis in Excel
Run ANOVA in SPSS
Identify trends and themes for level 2
Level 3 Coding – Themes and Results
Run descriptive analysis in Excel
Check box table for Themes
Develop table summary and results

The statistical analysis program SPSS was used conduct Pearson correlations that existed within the data. The open-ended questions were coded and entered into Microsoft Excel. Trends and themes were identified in the examination of that data. The final stage of the analysis was examining the final coding and the identification of trends and themes that existed not only in the free response and the statistical data, but confirmed by having compared it against the materials themselves. It was from this final evaluation and reporting, that the results were produced and discussed in future chapters.

Analysis Process

The first phase of the process after collecting material items, was evaluating material with the use of the rubrics; which included answering the yes-no questions, followed by the Likert scale questions and the free response justification questions and the grade appropriate question. First part of the rubric that needed to be completed was the yes-no questions, which dictated whether or not there was evidence of that particular concept in the material. Should the answer be no, then the Likert question would be answered with a score of one and a brief statement specifying that there was no evidence of that particular concept present in the material. If the answer was yes, then the material would have been evaluated for the extent by which that particular concept had been present in the material with the Likert scale. A short statement for the free response question, which asked for a justification of the Likert scale rating, would be provided for the final portion of that concept. These steps were repeated for each progressive question. The final question of the rubric asked whether or not the material was grade appropriate for the level specified in the material. Upon answering yes or no, a brief justification was provided.

The first page of the rubric required the completion of the document title, the organization that published it and the targeted grade levels for the material. In addition, the front of the rubric also contained a table for summary input of the Likert scale responses, along with a box for the response of yes or no to the grade appropriate question. The rubrics were filled out for each material item and represented the raw data that were used in the analysis.

The second phase consisted of several parts, the first of which was termed Level I coding, followed by both quantitative and qualitative analysis. Level I coding involved the identification and transcribing of the data from the rubrics on to an Excel spreadsheet. Table 7 outlines Level I codes used not only in this phase of the analysis, but was also used in other phases as well. The table provided the coding used for the seven crosscutting concepts, and the 21 subcategories.

Table 7
Level 1 Coding - Data Entry

Code	Item
P	Patterns
CE	Couse and Effect
SPQ	Scale, Proportion and Quantity
SSM	Systems and Systems Models
EM	Energy and Matter
SF	Structure and Function
SC	Stability and Change
P-S	Patterns: Science Crosscutting Concepts
P-E	Patterns: Engineering Crosscutting Concepts
P-A	Patterns: Application of the Engineering Crosscutting Concept
CE-S	Couse and Effect: Science Crosscutting Concepts
CE-E	Couse and Effect: Engineering Crosscutting Concepts
CE-A	Couse and Effect: Application of the Engineering Crosscutting Concept
SPQ-S	Scale, Proportion and Quantity: Science Crosscutting Concepts
SPQ-E	Scale, Proportion and Quantity: Engineering Crosscutting Concepts
SPQ-A	Scale, Proportion and Quantity: Application of the Engineering Crosscutting Concept
SSM-S	Systems and Systems Models: Science Crosscutting Concepts
SSM-E	Systems and Systems Models: Engineering Crosscutting Concepts

SSMA	Systems and Systems Models: Application of the Engineering Crosscutting Concept
EM-S	Energy and Matter: Science Crosscutting Concepts
EM-E	Energy and Matter: Engineering Crosscutting Concepts
EM-A	Energy and Matter: Application of the Engineering Crosscutting Concept
SF-S	Structure and Function: Science Crosscutting Concepts
SF-E	Structure and Function: Engineering Crosscutting Concepts
SF-A	Structure and Function: Application of the Engineering Crosscutting Concept
SC-S	Stability and Change: Science Crosscutting Concepts
SC-E	Stability and Change: Engineering Crosscutting Concepts
SC-A	Stability and Change: Application of the Engineering Crosscutting Concept
GA	Grade Appropriate

Once the data were loaded into Microsoft Excel, the Likert data were analyzed using descriptive analysis through the Excel program to identify the mean and standard deviation of the responses. The descriptive analysis was run on the 21 Likert questions representing all of the subcategories in the rubric, three subcategories per concept. Descriptive analysis was performed on each of the subcategories of the rubric, which included: the science crosscutting concepts, the engineering crosscutting concepts, the application of the engineering crosscutting concepts question, and the primary question of grade appropriateness. Furthermore, descriptive analysis during this phase was also performed on each item, which looked at all 21 subcategory scores per material item; this provided a total of 45 independent scores for each material item. The statistical program of SPSS was used to analyze the data for possible correlations. Once the coded data were loaded into SPSS, a bivariate correlation analysis was conducted using Pearson correlation coefficients while testing for two tailed significance. The bivariate correlation analysis was conducted on all 21 Likert data sets. Bivariate correlation analysis was also conducted on each of the subcategories, including: the science crosscutting concepts, the engineering crosscutting concepts, application of the engineering crosscutting concepts, and the primary category of grade appropriateness.

When observing and processing the free response questions, an attempt was made to identify a theme or trend that could be used in the production of a second level set of coding. The observations made through the analysis of the free response questions were reported in the results chapter of the study. Through the observation and analysis of the free response questions, the descriptive analysis, and the correlation analysis; a second level of coding was developed to assist in the analysis and identification of results. Table 8 illustrates Level II coding that was used in the second phase of the analysis.

Table 8
Level 2 Coding – Organizations (O) and Topics (T)

Code	Item
CO	Commercial Organizations
NO	Non-Profit Organizations
GO	Government Organizations
PO	Professional Organizations
UO	University Organizations
VT	Topics that revolve around volcanic influence on earthquakes
WT	Topics that revolve around seismic waves
FT	Topics that revolve around fault zones
PT	Topics that revolve around plate tectonics
HT	Topics that revolve around human interaction
LT	Topics that revolve around the landscape

Level II coding which was referred to as organizations and topics. The organizations category introduced five new subcategories, including: commercial organizations, nonprofit organizations, government organizations, professional organizations, and university organizations. The topics category introduced six new subcategories, including: volcanic influence on earthquakes, seismic waves, fault zones, plate tectonics, human interaction, and landscapes. This next level of coding allowed for new trends and themes to be produced using the same techniques that were used in the

Level I coding with the new categories. Using the new Level II coding, the data were reentered into Excel and SPSS to be re-analyzed. In Excel, descriptive analysis was run to determine mean and standard deviation. Descriptive analysis was performed on each organization independently, and on each material item in each of the organizations. Once the coded data were loaded once again into SPSS, a bivariate correlation analysis was conducted using Pearson correlation coefficients while testing for two tailed significance. The bivariate correlation analysis was conducted on each organization independently.

The free response questions were also reorganized to be entered into Excel according to organization. This information was analyzed to identify trends and themes that were presence in this newly coded data. The results of this analysis were further discussed in the results chapter. The results of the free response analysis along with the descriptive analysis and the correlation analysis were used in the development of Level III coding. The Level III coding was the final set of codes used in the analysis of the study, and provided the sequencing for themes used in the final analysis and the determination of results. Level III coding was used to scrutinize the data for trends and concepts along with themes and ideas that helped develop the results of the study. Table 9 outlines Level III coding in the description of the codes.

Table 9
Level 3 Coding - Themes and Results Table

Code	Item
SCC	Science crosscutting concept
ECC	Engineering crosscutting concept
EA	Application of the engineering crosscutting concept
O	Organization
T	Topic
GA	Grade appropriate material
LL	Lecture included into material
AL	Activity included into material

RSA	Report style activity
RBA	Research based activity
HA	Hands-on activity
TM	Teacher materials included
SM	Student materials included
HS	High school centered material
EC	Elementary school material centered
K12	K-12 material centered

From the Level III coding, a check box table was developed to be used in the final analysis of the material. The checkbox table was used in evaluating the materials for subcategories, organization, and themes. Within the table, each material item was evaluated and the results entered in the table with a number, letter or check. For the subcategories in the table, the number of concepts in which the material item showed evidence was filled in with a number from 1 to 7 (as there are 7 concepts) of the value in which that item was present. The subcategories included the science crosscutting concept, the engineering crosscutting concept, and application of the engineering crosscutting concept. In the next part of the table, the checkbox asked which organizations the item belonged to, the topic of the material, and a check box for grade appropriateness. The rest of the boxes on the table related to the themes, and each item was evaluated as to whether or not that theme existed in the material. This was indicated with a simple check in the box. A total of 12 check box tables were created, they included a table for all items, a table for each individual organization and a table for each topic. The tables that were created for the organizations only had those items that related to the organizations entered, as did the tables for the topics. The check box table is illustrated in Figure 2 below.

Figure 2
Check Box Table Illustration

Item	Box	Check box description
SCC	1-7	For Boxes SCC, ECC, and EA a value between 1 and 7 are given to indicate the number of concepts present in each of the subcategories.
ECC	1-7	
EA	1-7	
GA	X	An "X" in this box indicates the material is grade appropriate.
O	Letter	The organization code is used in this box for the material (U, P, G, N, C)
T	Letter	The topic code is used in this box for the material (FT, HT, LT, PT, VT, WT)
LL	X	For the remaining boxes, an "X" indicates that the material contains the particular quality, theme or idea.
AL	X	
RSA	X	
RBA	X	
HA	X	
TM	X	
SM	X	
HS	X	
EC	X	
K12	X	

Using Excel, a numerical analysis was done to look at the percentage of the results as they compared to each other, and as they compared by organization. Observations were made through the analysis of the checkbox tables and the numerical analysis to determine and develop the final results of the study. Results of the check boxes, the numerical analysis and observations were discussed in the results chapter of the study.

Analysis Summary

This study consisted of several components all working together with few independent processes. Although this analysis process appeared to be linear, it was important to understand that each component relied on a previous component and at the same time developed later concepts. This was an effect of how the grounded theory method was used in this study, developing a cycle of statistical and numerical analysis along with the observation and development of codes to identify trends and themes in the data. From these observations, a theory was developed and checked against the available data to develop the results and provide a solution to the study.

Reliability and Validity

Validity for the rubric came in part from a publication by Keiser, Lawrence and Appleton titled *Technical Education Curriculum Assessment* (2004). It was determined that the TECA has a very high reliability and validity. Because material evaluation rubric was designed after the TECA framework, as a result the material evaluation rubric carried many of the same measurements and concepts that were originally associated with the TECA rubric. Validity also came from direct information that was obtained from the *NRC Framework*, by which definitions would be used in the development of the specific questions in the material evaluation rubric.

To assist in validating the Likert survey, information was been taken and studied to assure that proper use of the *NRC Framework* crosscutting concepts came directly from The National Research Council framework itself (NRC, 2011). The National Research Council had taken steps to ensure the validity and accuracy in producing the crosscutting concepts. To ensure this, scholars and professionals alike were organized and asked to develop these crosscutting concepts. It was by the fact that the crosscutting concepts were created through the combined efforts of experts in the field that made the assumption for validation of the questions that were used to help identify crosscutting concepts within the material. Further validation for this method also came from the *NRC Framework* crosscutting concepts developed by the National Research Council as it related to the specific content being addressed. These methods were developed by experts in their specific fields through collaboration and content analysis. Experts participating in the development of the *NRC Framework* crosscutting concepts included engineers, scientists, educators, and industry experts.

Reliability for these methods existed in three different means: previous studies, an internal verification of reliability, and evaluator. The first aspect of reliability stemmed from previous studies that were conducted by other researchers (Keiser, Lawrenz, Appleton, 2004). The use of a Likert scale survey to measure contents in curriculum materials were used numerous times an evaluation tool such as the TECA. Secondly, reliability was also checked using internal measurement. The two different evaluation (the numerical analysis and the free response analysis) tools used were compared against each other. A strong level of correlation did signify a strong level of reliability for the data. Through each of these different means reliability would be evident, and they were able to also validate each other. This was a result of being able to compare the Likert scores and statistical results to that of the free response results. Finally, the last aspect of reliability came from the notion that this study was conducted by a single researcher and as such, materials, instruments, and analysis were all performed in a uniformed manner allowing for consistency throughout the study. This provided for reliability in that only one evaluation source was used throughout the analysis process.

Chapter 4

RESULTS

Introduction

In this chapter, the results of the research are broken down into two primary sections, quantitative analysis and results and qualitative analysis and results. The quantitative section consists of four parts. The first part us the Level I results, which are the general coding of the material and the overall statistical, descriptive and free response analysis of the data. The second part is the Level II results that revolve around the organizational coding and are treated as a category in this chapter. The third part is the Level II results that revolved around the topical coding and also was treated as a category in this chapter. Both of the Level II results sections consist of the descriptive analysis, the statistical analysis, and the free response analysis. The final part was the Level III results that revolved around the final set of coding and theme analysis. The second section is the qualitative analysis and results. It is broken into 4 parts. The first part examines the rubric categories, the second part examines student activities, and the third includes organizational differences and last was grade appropriateness.

Throughout the chapter there are terms used to describe different groups or groupings: lessons, concepts, categories, subcategories, and items. Lessons describe the materials obtained for the study, which include the 45 samples retrieved from the internet. Concepts are used to describe the seven crosscutting concepts of the *NRC Framework*. Categories include three groups: the rubric categories (science crosscutting, engineering crosscutting, and application of engineering), the organization category and the topics category. The term rubric subcategory refers to the rubric categories within the concepts (i.e. science crosscutting of patterns, engineering crosscutting of cause and effect). Lesson topics refer to the subcategories of the topics category and organizational groups the subcategories of the organization category. The term Item was used to describe any single piece of information within one of the fore mentioned terms.

Quantitative Analysis and Results

Level I Results

The Level I results are looked at the data from different perspectives. The data were looked at in terms of the three rubric categories of, science crosscutting, engineering crosscutting, and application of engineering. Next, the data were examined in terms of the rubric free response descriptions, which include all rubric subcategories for trends and lesson characteristics. This section is broken up into two parts, they were: Level I descriptive analysis from Excel and analysis from the free response descriptions.

Level I descriptive analysis. In calculating the general descriptive analysis, calculations were performed from the Likert scale responses which ranged from 1 to 5. There were a total of 945 samples, given that each of the 45 lessons had 21 rubric subcategories. Each category had 315 samples, 45 lessons with seven concepts per category. Table 10 summarizes the descriptive analysis of all rubric subcategories in each of the rubric categories.

Table 10
Descriptive Analysis Summary for the Rubric Categories

Category	Sample Size[a]	Min	Max	Mean	SD
SCC	315	1	5	3.14	1.16
ECC	315	1	5	1.53	0.97
AE	315	1	4	1.30	0.72
All	945	1	5	1.99	1.27

Note. SCC = Science Crosscutting category; ECC = Engineering Crosscutting category; AE = Application

of Engineering Crosscutting category.
[a]Total number of subcategories in each category.

General descriptive analysis showed that the science crosscutting category had the highest mean amongst the three rubric categories. The highest in this category was stability and change subcategory and the lowest was structure and functions subcategory. . Table 11 summarizes the descriptive analysis of all the lessons for each of the crosscutting concepts in the category of science crosscutting.

Table 11
Descriptive Statistics for the Science Crosscutting Category (SCC) Organized by Concept

Concept	Sample Size[a]	Mean	SD
P	45	3.44	0.84
CE	45	3.31	1.23
SPQ	45	3.24	0.88
SSM	45	2.62	1.06
EM	45	3.38	1.20
SF	45	2.49	1.02
SC	45	3.53	1.13

Note. P = Patterns; CE = Couse and Effect; SPQ = Scale, Proportion and Quantity; SSM = Systems and Systems Models; EM = Energy and Matter; SF = Structure and Function; SC = Stability and Change.
[a]Total possible number of lessons per concept.

The general descriptive analysis showed that the engineering crosscutting category had the second highest mean amongst the three rubric categories. The highest mean in this subcategory belonged to scale, proportions, and quantities. The lowest in the subcategory belonged to the patterns subcategory. The lowest rubric subcategory was patterns of engineering crosscutting. Table 12 summarizes the descriptive analysis of all the lessons for each of the crosscutting concepts in the category of engineering crosscutting.

Table 12
Descriptive Statistics for the Engineering Crosscutting Category (ECC) Organized by Concept

Concept	Sample Size[a]	Mean	SD
P	45	1.18	0.65
CE	45	1.58	0.96
SPQ	45	1.98	1.28
SSM	45	1.44	0.81
EM	45	1.89	1.18
SF	45	1.40	0.74
SC	45	1.22	0.53

Note. P = Patterns; CE = Couse and Effect; SPQ = Scale, Proportion and Quantity; SSM = Systems and Systems Models; EM = Energy and Matter; SF = Structure and Function; SC = Stability and Change.
[a]Total possible number of lessons per concept.

The general descriptive analysis showed application of the engineering crosscutting had the lowest mean. The highest of the means in this rubric subcategory belonged to scale, proportions, and quantities. The lowest in this subcategory belonged to patterns. The lowest rubric subcategory was patterns of application of engineering. Table 13 summarized the descriptive analysis of all the lessons for each of the crosscutting concepts in the category of application of engineering crosscutting.

Table 13
Descriptive Statistics for Application of the Engineering Crosscutting Category (AE) Organized by Concept

Concept	Sample Size[a]	Mean	SD
P	45	1.11	0.56
CE	45	1.29	0.63
SPQ	45	1.60	1.03
SSM	45	1.22	0.52
EM	45	1.49	0.91
SF	45	1.22	0.50
SC	45	1.15	0.38

Note. P = Patterns; CE = Cause and Effect; SPQ = Scale, Proportion and Quantity; SSM = Systems and Systems Models; EM = Energy and Matter; SF = Structure and Function; SC = Stability and Change.
[a]Total possible number of lessons per concept.

Both the engineering crosscutting category and the application of engineering crosscutting category, showed smaller means that were nearly equivalent. These two categories also showed that the lowest and the highest rubric subcategories were the same, the lowest being patterns and the highest being scale, proportions, and quantities.

The high mean for the science crosscutting category indicated that the majority of lessons incorporated the crosscutting concepts as they relate to science content. The low mean for the engineering crosscutting category as well as the application of the engineering crosscutting category showed that a majority of the lessons did not contain evidence of those concepts.

For the evaluation of grade appropriateness, it was determined that only seven lessons were considered in appropriate for the designated grade, with the remaining 38 lessons grade appropriate. The 38 lessons were considered grade appropriate if the material and activities were appropriate for the grade range indicated on the lesson by having demonstrated accurate grade level content, vocabulary and activities. The seven lessons that were not grade appropriate ether did not meet the material or activity target range, or the intended grade range indicated in the lesson was not the same as listed on the web site.

Level I open-ended description analysis. Results of the justification for scoring, also known as the free response coding, were compared and analyzed in several different groupings and codings. It was the result of this analysis that provided for the second level coding and the categories of organizations and topics. When the documents were looked at as a whole, only 2 of the 45 lessons showed evidence of all 21 subcategories along with the grade appropriate question and held the rank of first and second. More specific discussion on the lessons will occur later in the chapter. In general, as the ranking became lower, so did the number of subcategories represented.

In the category of science crosscutting, themes were developed from the open-ended descriptions. Table 14 provides a summary of the lesson characteristics found in the science crosscutting category separated by concept.

Table 14
Lesson Characteristics Present in the Category of Science Crosscutting

Concept	Themes Present
Patterns	• Human involvement patterns • Geological patterns • Fault zones • Seismic waves • Tsunami • Earthquake
Cause and Effect	• Buildings and Structures • Fault zones • Plate tectonics • Geological • Volcanoes • Tsunami • Lesson activates • Waves • Equipment
Scale, Proportion and Quantity	• Maps and diagrams • Physical models • Printed models • Data tables • Quantity assessments
System and System Models	• Geological systems • Wave systems • Human systems • System of physical models • System of buildings and structures
Energy and Matter	• Transfer of energy - ground • Transfer of matter - ground • Energy as waves • Transfer of energy to building
Structure and	• Structure and function of buildings

Function	• Geological features • Geological events • Function of physical models • Function of waves • Function of equipment
Stability and Change	• Stability of geological features • Change of geological features • Stability of fault zones • Change of fault zones • Change in waves

In the overall summary of the science crosscutting category, there were few instances where lessons did not display any level of evidence.

In the category of engineering crosscutting, themes were developed from the open-ended descriptions. Table 15 provides a summary of the lesson characteristics found in the engineering crosscutting category separated by concept.

Table 15
Lesson Characteristics Present in the Category of Engineering Crosscutting

Concept	Themes Present
Patterns	• Building and structure failure
Cause and Effect	• Physical models of building and structures • Models of faults • Models of waves
Scale, Proportion and Quantity	• Models to demonstrate waves • Models of building • Models of fault zones • Models of geological features
System and System Models	• Parts of a model • Parts of building • Parts of geological features
Energy and Matter	• Energy in the movement of the model • Damage done to buildings • Movement of building
Structure and Function	• Function of physical models • Function of buildings

	• Function of equipment
Stability and Change	• Building stability • Physical models demonstrating change - geological

In the overall summary of the engineering crosscutting category, approximately two-thirds of the lessons exhibited some level of evidence within the category. Only two lessons showed evidence of all seven crosscutting concepts within the engineering crosscutting category. They all demonstrated the use, process or building of a model to demonstrate the lesson.

In the category of application of engineering crosscutting, themes were developed from the open-ended descriptions. Table 16 provides a summary of the lesson characteristics found in the application of engineering crosscutting category separated by concept.

Table 16
Lesson Characteristics Present in the Category of Engineering Application of Crosscutting Concepts

Concept	Themes Present
Patterns	• Building and structure failure activity • Wave patterns in the physical movement of a model
Cause and Effect	• Manipulation of models of building and structures • Manipulation of models of faults • Manipulation of models of geological concepts
Scale, Proportion and Quantity	• Shaking physical models for earthquakes • Modeling the physical slipping of faults • Building models of geological concepts • Active models for wave movement
System and System Models	• Building models with different parts • Interacting parts of building
Energy and Matter	• Energy in the movement of the model • Damage done to buildings

	• Movement of building
Structure and Function	• Demonstrating function of physical models • Demonstrating function of buildings • Demonstrating function of equipment
Stability and Change	• Designing building stability • Manipulating change in models

In the overall summary of the application of engineering crosscutting category, approximately one fourth of the lessons exhibited some level of evidence within the category. Two lessons showed evidence of all seven crosscutting concepts within the application of engineering crosscutting subcategory. All lessons within the category exhibited a hands-on application or activity.

Level II Results - Organization

The purpose of Level II analysis was to approach the data from two additional categories, using two different sets of coding. The two new additional categories included organizations and topics. Each of these two categories had its own sets of results from its own sets of analysis. Within the coding for organizations, there were five organizational groups, they included: commercial organizations, nonprofit organizations, government organizations, professional organizations, and university organizations. This section was broken down into three subsections, including: Level II descriptive analysis for organizations, Level II statistical analysis for organizations, and Level II open-ended description analysis for organizations.

Level II descriptive analysis for organization. As in the Level I descriptive analysis, the calculations were performed from the Likert scale scores which again ranged from 1 to 5. Appendix D provides a summary of the descriptive analysis for the organizations groups and all the rubric subcategories.

In general, there was little difference in the range of the organizational groups. Table 17 summarizes the descriptive analysis for each of the organizational groups.

Table 17
Descriptive Statistics for Overall Average of the Means for the Organization Groups

Organization	Sample Size	Min	Max	Mean	SD
CO	7	1.29	3.71	1.95	0.85
GO	7	1.48	2.95	1.84	0.52
NO	15	1.38	3.24	1.98	0.55
PO	4	1.48	2.62	1.98	0.51
UO	12	1.57	3.05	2.10	0.43

Note. CO = Commercial Organizations; NO = Non-Profit Organizations; GO = Government Organizations; PO = Professional Organizations; UO = University Organizations.

Level II ANOVA analysis for organization. The ANOVA analysis was conducted on the sums of the rubric subcategories scores with in each of the rubric categories to that of the five organizational groups. Three ANOVA analyses were completed; one for each of the rubric categories analyzing the organizational groups. Table 18 summarizes the results of the ANOVA results for each of the rubric categories.

Table 18
ANOVA Results for Organizations

Lessons	*N*	F (v_1, v_2)	*p*
SCC	45	1.18 (4, 40)	0.334
ECC	45	0.11 (4, 40)	0.979
AE	45	0.06 (4, 40)	0.994

Note. SCC = Science Crosscutting category; ECC = Engineering Crosscutting category; AE = Application of Engineering Crosscutting category.

Results of the ANOVA showed no statistical differences among the organizations for any of the rubric categories.

Level II open-ended description analysis for organization. The purpose of this free response analysis was to identify themes and trends that existed when the data were categorized by organization. The re-categorization of the data into organizations was the result in part by Level I analysis. It was from the Level I analysis that the two new categories of organizations and topics were developed. In this section only the category of organizations was analyzed for trends and themes specific to each one of the five organizations. Results from this analysis were used in part to help identify and create the Level III coding and analysis.

The following lesson characteristics were identified in the seven lessons of the commercial organization free response descriptions. One of the lessons showed evidence of all 21 rubric subcategories. One lesson showed evidence of all seven science crosscutting subcategories, and four of the engineering crosscutting subcategories, but lacked any of the application of engineering subcategories. While one lesson included all of the seven science crosscutting subcategories, but no other rubric categories. The remaining four lessons included between four and five the science crosscutting category, and no other rubric categories. Materials all focused on different themes, while two of the lessons provided hands on activities with modeling.

The following lesson characteristics were identified in the 15 lessons of the non-profit organization free response descriptions. One of the lessons showed evidence of all 21 rubric subcategories. The rest of the lessons in this organizational category were missing the subcategories of engineering crosscutting of patterns and application of engineering for patterns; however, all lessons demonstrated the science crosscutting subcategories. Six of the lessons showed additional evidence of the engineering crosscutting subcategories. Five of the lessons showed evidence of all three rubric categories. Materials focused on different themes, and five lessons contained hands on activities with modeling.

The following lesson characteristics were identified in the four lessons of the professional organization for the free response descriptions. All lessons in this organizational category were missing five rubric subcategories. The missing subcategories included patterns of engineering crosscutting, system and system models of engineering crosscutting; and patterns of application of engineering crosscutting, systems and system models of application of engineering crosscutting and structure and function of application of engineering crosscutting. All lessons demonstrated the science crosscutting subcategories. Two of the lessons showed evidence of all three rubric categories. Materials focused on waves or geological change, and one lesson contained a hands-on activity with modeling.

The following lesson characteristics were identified for the 12 lessons of the university organization free response descriptions. All lessons in this organizational category were missing the subcategories of engineering crosscutting of patterns and application of engineering for patterns; however, all lessons demonstrated the science crosscutting subcategories. Eleven of the lessons showed additional evidence of the engineering crosscutting subcategories. Five of the lessons showed evidence of all three rubric categories. Materials focused on different themes, and six of the lessons contained a hands-on activity with modeling.

The following lesson characteristics were identified for the seven lessons of the government organization free response descriptions. All lessons in this organizational category were missing the subcategories of engineering crosscutting of patterns and application of engineering for patterns; however, all lessons demonstrated the science crosscutting subcategories. Two of the lessons showed additional evidence of the engineering crosscutting subcategories. The same two the lessons showed evidence of application of engineering crosscutting subcategory. Materials in this category focused on different themes, and two of the lessons contained a hands-on activity with modeling.

Level II Results - Topics

The purpose of Level II analysis was to approach the data from two additional categories, using two different sets of coding. The two new additional categories include organizations and topics. Each of these two categories has its own sets of results from its own sets of analysis. For the coding for topics, it included six lesson topics, they included: fault zones, human interaction, landscape, plate tectonics, volcanic, and seismic wave. In both groups of coding, the same rubric subcategories exist in this portion analysis that did in the Level I analysis. This section has been broken down into three subsections, including: Level II descriptive analysis for topics, Level II statistical analysis for topics, and Level II open-ended description analysis for topics.

Level II descriptive analysis for topics. As in the Level I descriptive analysis, the calculations were performed from the Likert scale responses which again ranged from 1 to 5. Appendix E shows a summary of the descriptive analysis for each of the rubric subcategories in each of the lesson topics.

Table 19 summarizes the descriptive analysis for the means and standard deviations for all lesson topics.

Table 19
Descriptive Statistics for Overall Average of the Means for the lesson characteristics

Topic	Sample Size	Minimum	Maximum	Mean	SD
FT	7	1.52	3.05	2.46	0.52
HT	13	1.29	3.71	1.79	0.64
LT	6	1.43	3.24	1.98	0.65
PT	8	1.48	2.62	1.98	0.40
VT	3	1.48	2.38	1.95	0.45
WV	8	1.48	2.52	1.93	0.40

Note. VT = Topics that revolve around volcanic influence on earthquakes; WT = Topics that revolve around seismic waves; FT = Topics that revolve around fault zones; PT = Topics that revolve around plate tectonics; HT = Topics that revolve around human interaction; LT = Topics that revolve around the landscape.

Level II ANOVA analysis for topics. The ANOVA analysis was conducted on the sums of the rubric subcategories scores with in each of the rubric categories to that of the six lesson topics. Three ANOVA analyses were completed; one for each of the rubric categories verses the lesson topic. Table 20 summarizes the results of the ANOVA results for each of the rubric categories.

Table 20
ANOVA Results for Topic

Category	N	$F\ (v_1, v_2)$	p
SCC	45	1.53 (5, 39)	0.202
ECC	45	1.48 (5, 39)	0.219
AE	45	1.49 (5, 39)	0.216

Note. SCC = Science Crosscutting category; ECC = Engineering Crosscutting category; AE = Application of Engineering Crosscutting category.

Results of the ANOVA showed no statistical differences among the lesson topics for any of the rubric categories.

Level II open-ended description analysis for topics. The purpose of this free response analysis was to identify lesson characteristics that existed when the data were categorized by topics. The re-categorization of the data into topics was the result in part by Level I analysis. It was from the Level I analysis that the two new categories of organizations and topics were developed. In this section only the category of topics were analyzed for trends and themes specific to each one of the six topics. Results from this analysis were used in part to help identify and create the Level III coding and analysis.

The following lesson characteristics were identified in the seven fault zone lesson topic free response descriptions. All lessons in this topic were missing the rubric subcategories of engineering crosscutting of patterns and application of engineering for patterns; however, all lessons demonstrated the science crosscutting subcategories. Six of the lessons contained both the engineering crosscutting subcategories and the application of engineering subcategories. In this lesson topic, six lessons contained hands on modeling activities. The activities included use of foam and wooden blocks for fault zone demonstrations.

The following lesson characteristics were identified in the13 human interaction lesson topic free response descriptions. Two of the lessons showed evidence of all 21 rubric subcategories. Three of the lessons had evidence in both the science and the engineering crosscutting subcategories. The remaining eight lessons in this lesson topic were missing the subcategories of engineering crosscutting and the application of engineering for: patterns; cause and effect; scale, proportions and quantity; system and system models; structure and function; and stability and change. In this lesson topic, two lessons had hands-on modeling activities, which demonstrated damage done to buildings and structure as a result of earthquakes.

The following lesson characteristics were identified in the six landscape lesson topic free response answers. One of the lessons had evidence in both the science and the engineering crosscutting subcategories. The remaining five lessons in this lesson topic were missing the subcategories of engineering crosscutting and the application of engineering for: patterns; cause and effect; scale, proportions and quantity; system and system models; structure and function; and stability and change. However, all lessons demonstrated the science crosscutting subcategories. In this lesson topic, no lesson had a hands-on modeling activity.

The following lesson characteristics were identified in the eight plate tectonics lesson topic free response descriptions. All lessons in this topic were missing the rubric subcategories of engineering crosscutting of patterns and application of engineering for patterns; however, all lessons demonstrated the science crosscutting subcategories. One of the lessons had additional evidence of the science crosscutting subcategories, but not the engineering crosscutting subcategories. Three of the lessons contained both the engineering crosscutting subcategories and the application of engineering subcategories. In this lesson topic, three lessons contained hands on modeling activities. The activities were building scale models of the crust, and the making of puzzles.

The following lesson characteristics were identified in the three volcanic related lesson topic free response descriptions. One of the lessons had evidence in both the science and the engineering crosscutting subcategories, but no application of engineering subcategory. The remaining two lessons in this lesson topic were missing the subcategories of engineering crosscutting and the application of engineering for: patterns; cause and effect; scale, proportions and quantity; system and system models; energy and matter; structure and function; and stability and change. In this lesson topic, there were no lessons containing hands-on modeling activities.

The following lesson characteristics were identified for the eight seismic wave lesson topic free response descriptions. All lessons in this topic were missing the rubric subcategories of engineering crosscutting of patterns and application of engineering for patterns; however, all lessons demonstrated the science crosscutting subcategories. Four of the lessons additionally contained both the engineering crosscutting subcategories and the application of engineering subcategories. In this lesson topic, four lessons contained hands on modeling activities. The activities included the use of slinkys, and making a tsunami in a bottle.

Level III Results

The general results of Level III coding involved identifying themes within the documents. In this analysis there are three primary components to this level of coding, they were: the rubric categories, organization and topic categories, and the newly embedded themes categories. The analysis was conducted in two parts, they were: lessons by organization, and lessons by topic.

The analysis for the category of organizational material was as follows: five tables were produced to show a summary of the basic numerical analysis as described above for each of the organizations.

Table 21 summarized the number of lessons in each of the organization groups that contained the rubric categories and lesson characteristics; (n) represents the total number of lessons possible if all themes were present.

Table 21
Evidence of Rubric Categories and Themes in Organizations - Quantity

Theme	Number of themes present in each organization group					
	UO	NO	GO	CO	PO	Overall
(n)	12	15	7	7	4	45
SCC	13	15	7	7	4	45
ECC	11	7	3	2	2	23
EA	6	5	2	1	2	16
LL	10	10	7	3	1	31
AL	11	15	7	6	4	43
RSA	9	15	7	5	4	40
RBA	8	14	4	5	3	34
HA	6	5	2	1	2	16
GA	10	15	3	6	4	38
TM	10	15	7	7	3	42
SM	12	11	3	2	4	32
HC	7	8	1	3	3	22
EC	1	0	0	3	0	4
K12	2	7	6	1	0	16

Note. SCC = Science crosscutting category; ECC = Engineering crosscutting category; EA = Application of the engineering crosscutting category; GA = Grade appropriate material; LL = Lecture included into material; AL = Activity included into material; RSA = Report style activity; RBA = Research based activity; HA = Hands-on activity; TM = Teacher materials included; SM = Student materials included; HS = High school centered material; EC = Elementary school material centered; K12 = K-12 material centered; CO = Commercial Organizations; NO = Non-Profit Organizations; GO = Government Organizations; PO = Professional Organizations; UO = University Organizations; (n) = total number of lessons for that category.

The number of lessons in each of the organization category tables was taken into account when calculating the percentage scores for the rubric categories and themes in each of the organizational groups. Table 22 summarizes the percentage of lessons in each of the organization groups that contained the rubric categories and lesson characteristics.

Table 22
Evidence of Rubric Categories and Themes in Documents - Percent

Theme	Percent (Proportionally) of Items in Each Organization					
	UO	NO	GO	CO	PO	Overall
SCC	100	100	100	100	100	100

ECC	92	47	43	29	50	50
EA	50	33	29	14	50	35
LL	83	67	100	43	25	69
AL	92	100	100	86	100	96
RSA	75	100	100	71	100	89
RBA	67	93	57	71	75	76
HA	50	33	29	14	50	36
GA	83	100	43	86	100	84
TM	83	100	100	100	75	93
SM	100	73	43	29	100	71
HC	58	53	14	43	75	49
EC	8	0	0	43	0	9
K12	17	47	86	14	0	36
Mean	61	64	56	51	59	60

Note. SCC = Science crosscutting category; ECC = Engineering crosscutting category; EA = Application of the engineering crosscutting category; O = Organization; T = Topic; GA = Grade appropriate material; LL = Lecture included into material; AL = Activity included into material; RSA = Report style activity; RBA = Research based activity; HA = Hands-on activity; TM = Teacher materials included; SM = Student materials included; HS = High school centered material; EC = Elementary school material centered; K12 = K-12 material centered; CO = Commercial Organizations; NO = Non-Profit Organizations; GO = Government Organizations; PO = Professional Organizations; UO = University Organizations.

The analysis for the category of topic lessons is as follows: six tables were produced to show a summary of the basic numerical analysis as described for each of the lesson topics. The lesson topics included: fault zones, plate tectonics, human interaction, volcanic influence, landscape changes, and seismic waves. The number of items in each of the lesson topics tables was taken into account when calculating the percentage scores for each of the themes in each of the topic tables. Table 23 summarizes the number of lessons in each of the rubric categories and lesson characteristics; (n) represents the total number of lessons possible if all themes were present.

Table 23
Evidence of Rubric Categories and Themes in Lesson Topics - Quantity

Theme	Number of Items in each Topic						
	FT	HT	LT	PT	VT	WT	Overall
(n)	7	13	6	8	3	8	45

SCC	7	13	5	8	3	8	45
ECC	6	4	3	4	1	5	23
EA	6	3	0	3	0	4	16
LL	7	7	6	6	1	4	31
AL	7	13	5	7	3	8	43
RSA	7	11	5	6	3	8	40
RBA	5	11	5	6	3	4	34
HA	6	2	0	3	0	4	16
GA	6	12	5	7	3	6	38
TM	7	13	6	7	3	6	42
SM	4	9	5	6	3	5	32
HC	4	6	1	6	1	4	22
EC	0	3	1	0	0	0	4
K12	2	4	3	1	2	4	16

Note. SCC = Science crosscutting category; ECC = Engineering crosscutting category; EA = Application of the engineering crosscutting category; GA = Grade appropriate material; LL = Lecture included into material; AL = Activity included into material; RSA = Report style activity; RBA = Research based activity; HA = Hands-on activity; TM = Teacher materials included; SM = Student materials included; HS = High school centered material; EC = Elementary school material centered; K12 = K-12 material centered; VT = Topics that revolve around volcanic influence on earthquakes; WT = Topics that revolve around seismic waves; FT = Topics that revolve around fault zones; PT = Topics that revolve around plate tectonics; HT = Topics that revolve around human interaction; LT = Topics that revolve around the landscape. (n) = total number of lessons for that category.

The number of lessons in topic category table was taken into account when calculating the percentage scores for the rubric categories and lesson characteristics in each of the organizational groups. Table 24 summarizes the percentage of lessons that contained the lesson characteristics in the topic category.

Table 24
Evidence of Rubric Categories and Themes in Documents - Percent

Theme	Percent (Proportionally) of Items in Each Topic						
	FT	HT	LT	PT	VT	WT	Total
SCC	100	100	100	100	100	100	100
ECC	85	31	50	50	33	63	50
EA	85	23	0	38	0	50	36
LL	100	54	100	75	33	50	69
AL	100	100	83	88	100	100	96
RSA	100	85	83	75	100	100	89
RBA	71	85	83	75	100	50	76

HA	86	15	0	38	0	50	36
GA	86	92	83	88	100	75	84
TM	100	100	100	88	100	75	93
SM	57	69	83	75	100	63	71
HC	57	46	17	75	33	50	49
EC	0	23	17	0	0	0	9
K12	29	31	50	13	67	50	36
Mean	70	58	60	58	61	57	60

Note. SCC = Science crosscutting category; ECC = Engineering crosscutting category; EA = Application of the engineering crosscutting category; O = Organization; T = Topic; GA = Grade appropriate material; LL = Lecture included into material; AL = Activity included into material; RSA = Report style activity; RBA = Research based activity; HA = Hands-on activity; TM = Teacher materials included; SM = Student materials included; HS = High school centered material; EC = Elementary school material centered; K12 = K-12 material centered; VT = Topics that revolve around volcanic influence on earthquakes; WT = Topics that revolve around seismic waves; FT = Topics that revolve around fault zones; PT = Topics that revolve around plate tectonics; HT = Topics that revolve around human interaction; LT = Topics that revolve around the landscape.

Qualitative Analysis and Results

Science, Engineering and Application of Engineering Categories

The descriptive analysis indicated that the lessons showed greater evidence of the science crosscutting while demonstrating a lack of the engineering crosscutting concepts. This was not surprising as the lessons were designed with current science standards in mind, which did not include engineering content. An examination of the lessons, their activities and presence of student centered inquiry supported this conclusion. There were no lessons that contained only engineering crosscutting without the presence of the science crosscutting. The majority of the lessons were such that there was the science crosscutting concept to some degree, but absence of the engineering crosscutting or application of the engineering crosscutting.

The science crosscutting category. All of the lessons showed at least one concept with a strong science crosscutting category, 45 out of 45 lessons. Even the lessons with the lowest overall scores demonstrated that the science crosscutting concepts were present. The following lessons showed some evidence of the science crosscutting category, but no engineering crosscutting, they represented 12 or 27% of the lessons.

Lesson 26: Students will learn to read maps of plate tectonics. Identify areas of earthquake activity on a map. (Concepts: patterns; system and system model)

Lesson 30: Students will access and interpret data online from USGS, plot earthquakes on a map. (Concepts: patterns; cause and effect)

Lesson 39: Students will learn about the San Francisco earthquake of 1906 by reading an article, and then students will answer worksheet questions about the earthquake. (Concepts: cause and effect; stability and change)

There were also lessons that had a strong science crosscutting presence with no engineering crosscutting presence. A strong presence was described as being a primary part of the lesson, and not secondary to the lesson. The following lessons demonstrated having a strong science crosscutting influence but lacked any engineering crosscutting; they represented 8 or 18% of the lessons.

Lesson 21: Students will observe fault movement on a computer generated model. Students will color a 3-D model using crayons. Students will answer a series of questions relating to fault movement. (Concepts: patterns; cause and effect; energy and matter; structure and function; stability and change)

Lesson 31: Students will locate GPS locations and interpret information on a global velocities map with regard to fault zones. Students will also determine the speed at which locations are moving and draw conclusions and identify trends from collecting data. (Concepts: patterns; scale, proportion and quantity; system and system model; energy and matter; structure and function; stability and change)

Lesson 37: Students will describe the causes of earthquakes and identify where they are likely to occur. Using online resources students will explore the effects of earthquakes on the geology of an area. Students will explain why it is important to be able to predict their occurrences. (Concepts: patterns; cause and effect; scale, proportion and quantity; system and system model; energy and matter; structure and function; stability and change)

The engineering crosscutting category. The next group looked at lessons as they related to the engineering crosscutting and the application of engineering crosscutting categories. The previous section looked at the different aspects of evidence in the science crosscutting categories. In this set of lessons, examples of weak evidence for the engineering crosscutting were demonstrated. A weak presence was described as being a secondary part of the lesson, and not specifically introduced as part of the lesson. All of these lessons contained science crosscutting evidence and no application of engineering evidence; they represented 6 or 13% of the lessons.

Lesson 6: Students will create maps depicting subduction zones, fault zones and plate boundaries. Students will use maps to answer questions relating to those topics. (Concepts: scale, proportion and quantity)

Lesson 9: After reading informational articles, students will discuss how earthquakes damaged buildings and ideas needed to design and build earthquake safe structures and buildings. (Concepts: cause and effect; structure and function)

Lesson 18: Students will compare earthquake magnitudes and the damage they did to buildings, and use their findings to predict the damage done by future earthquakes. (Concepts: energy and matter)

The next set of lessons showed stronger evidence of the engineering crosscutting concepts, but still lacked evidence for the application of the engineering crosscutting concepts. As we moved into the engineering crosscutting concepts, along with the application of the engineering crosscutting concepts there were fewer examples to illustrate these ideas as noted by a lack of supporting evidence, they represented 8 or 18% of the lessons.

Lesson 1: Students will utilize the process of scientific inquiry to introduce students to the tools of Google Earth and virtual ocean to explore fault zones in the ocean. Students will use this information to produce a 3-D visualization of subduction zones and fault zones around Alaska. Students will also uses information in order to identify and predict dangers to human colonization in and around those areas. (Concepts: cause and effect; scale, proportion and quantity; energy and matter)

Lesson 3: Students will use a GPS computer program from the Internet to access locations along with data from the plate boundary observation to create a visual model to reflect the velocity and movements of plates. (Concepts: cause and effect; scale, proportion and quantity; system and system model; energy and matter; structure and function)

Lesson 25: Using data sheets, students will design virtual building to withstand earthquakes of different magnitudes. Students will also examine information on building failures during earthquakes for additional information. (Concepts: patterns; cause and effect; structure and function; stability and change)

The application of engineering crosscutting category. The relationship between the engineering crosscutting concepts and that of the application of the engineering crosscutting concepts was very similar in quantity and quality in the lessons. In this set of lessons, there was a weak demonstration of the application of the engineering crosscutting concepts presented. Students were also guided with instruction and direction as to how complete the task without any real inquiry except for to look for answers to the questions provided in the worksheets, they represented 5 or 11% of the lessons.

Lesson 7: Students will use a slinky to mimic seismic wave motions and to demonstrate the difference between S, P, Rayleigh, and Love waves. Students use this demonstration to answer questions on a worksheet. (Concepts: system and system model; energy and matter)

Lesson 8: Students will draw on and cut foam pieces to demonstrate fault movements, including: normal faulting, reverse faulting, horizontal slip faulting. Students will use this demonstration to answer questions on a worksheet. (Concepts: cause and effect)

Lesson 36: Students will take wooden blocks and by using rubber bands connect them to the wood blocks to demonstrate slip motion faults. Students will use information gathered from the demonstration to answer questions on a worksheet. (Concepts: scale, proportion and quantity; system and system model)

In this next set of lessons, the applications of engineering concepts were presented with stronger evidence. This next group supported the idea that students were to be more involved in the design and development of the activity, rather than simply following directions. These lessons demonstrated more of an inquiry-based lesson and practice of engineering; they represented 4 or 9% of the lessons.

Lesson 17: Given a slinky, students will design and develop a means by which to demonstrate P waves, S waves, Rayleigh waves, Love waves, surface waves, at the center, and ruptures. Upon completion of this activity, students will design and develop another means by which to demonstrate the waves not using a slinky. (Concepts: scale, proportion and quantity; system and system model; energy and matter)

Lesson 33: Using a box, a board, sandpaper, and other simple materials, students will apply scientific and engineering methods along with basic math skills to create a model to demonstrate stick-slip movements, calculate averages, and plot their information on graphs. (Concepts: scale, proportion and quantity; system and system model; energy and matter; structure and function)

Lesson 38: This was the only lesson that contains an engineering application concept that was intended specifically for elementary school students. Students will be asked to bake pancakes and observe how they cooked and cooled down. Students will be asked to make adjustments to the amount and the consistency of the pancake batter used in creating the pancakes to adjust the events that occurred as the pancake baked and cooled down. (Concepts: cause and effect; scale, proportion and quantity; energy and matter)

In these two lessons, all of the rubric subcategories were present; these were the only two lessons with all of the rubric subcategories. It was also important to point out that these two lessons also had the highest mean score of the lessons. Their place there did not indicate that they were the strongest in all categories, but that they simply contained all the rubric subcategories, they represented 2 or 4% of the lessons.

Lesson 19: Students will understand that earthquakes may result in damage in the form of structural failure, soil liquefaction, and landslides. Students will also understand why certain areas and structures are more prone to damage than others. Through hands-on activities, students will model the relationship between shaking and landslides, and determine the factors that cause soil liquefaction. Students will use a computer simulation to determine the best bridge structures to withstand earthquakes of varying magnitudes.

Lesson 23: Students will be able to achieve an understanding by exploring different materials, shapes, and design options that affect the durability of a building and other structures. Students will understand how to use models to perform controlled scientific experiments. Students will design and build tabletop earthquake generators with a given set of supplies.

Students will gain an understanding as a how the distribution of weight within a structure affects the stability during an earthquake.

In summary, the qualitative analysis examined lessons for the science crosscutting concepts, the engineering crosscutting concepts, and the application of engineering crosscutting concepts. As the evidence demonstrated, the higher levels of use of crosscutting concepts were associated with higher levels of inquiry by the students.

Student Activities in the Lessons

In examining the lesson activities and examples, several key observations were made. It was noted that only a few topics were used in all the lessons along with the activities for the students. In all there were a total of 16 lessons that had a hands-on activity, or approximately 35% of the lessons. In general there were only four lesson characteristics that presented activities, they included: human interaction, seismic wave, plate tectonics, and fault zones.

Activities in the human interaction lesson topic. The common activity was creating model cities and buildings to demonstrate the effects of earthquakes on them. There were two examples of this, which represented 2 of the 16 lessons with activities or 13% of the lessons that had a hands-on activity.

Lesson 19: Students will design and build a model to demonstrate earthquakes and soil liquefaction using the following items: cornstarch, water, plastic box, newspaper, and other objects that fit into the box. Students will also design and build an earthquake table, using electric sander and a tabletop.

Lesson 23: Students will be given assorted supplies to design and develop an earthquake table. Items will include PVC, plywood, rubber bands, bolts, and other items that students can obtain. Students can use any number of electronic devices or manual devices to create the shaking motion of the table.

Activities in the fault zone topics. The group also included a narrow array of examples and activities. In this group of lessons, the common activity was the use of foam blocks and a wooden box to demonstrate slip faults and other fault movement. There were six examples of this, which represented 6 of the 16 lessons with activities or 38% of the lessons that had a hands-on activity.

Lesson 5: Students will be provided small blocks of wood, rubber bands and sandpaper to build an earthquake machine to represent elastic rebound. Students will be provided with step-by-step instructions for the building and use of the machine.

Lesson 8: Students will be given phone blocks, felt pens, rubber cement, pens, and Styrofoam to build models to demonstrate different fault movements and patterns. Students will also be given a set of directions to instruct them on the building and use of the demonstration model.

Lesson 16: Students will be given blocks of rubber foam to create a demonstration of fault movement. Students will be given directions to instruct them on the building and use of the demonstration model.

Activities in the topic of plate. This topic had the most diversity in the activities and examples for students. There were four lessons of this topic, which represented 4 of the 16 lessons with activities or 25% of the lessons that had a hands-on activity. Three of these activities were noted below.

Lesson 12: Students will use a paint-by-numbers version of plate boundaries printed on paper. Students are then to color in the pieces and finally cut the pieces out. The puzzle pieces will be used to demonstrate how the plates slide along each other.

Lesson 27: Students will create a three-dimensional shoebox diagram of a section of the North America plate. Students will be given: a shoebox, styrofoam balls, glue, and other instruments used to put together the diorama. Students will be given a set of directions to instruct them on the building process.

Lesson 38: Students will mix batter in order to make pancakes. The pancakes will be baked on a griddle in order to demonstrate the creation of cracks and other faults. Specific directions will be given to the student and parents in order to successfully accomplish this activity.

Activities in the seismic wave topic. In this topic all of the activities used and required a slinky to demonstrate wave movements. All activities demonstrate the same concepts in about the same manner. None of the activities provided an inquiry-based activity, as they were all instruction and direction driven. There were four lessons, which represented 4 of the 16 lessons with activities or 25% of the lessons that had a hands-on activity for this topic. Three of these activities were noted below.

Lesson 10: Working with a partner, each student will be holding an end of the slinky and stretch it out on the floor until it is about 6 feet apart. A person will act as an earthquake, and be instructed to pull the slightly towards them and then push away.

Lesson 17: Students will be asked to use the slinky to demonstrate and generate their own S and P waves. Students will also then be asked to demonstrate surface waves.

Lesson 35: Students will simulate the ways of an earthquake using a slinky. Two students will hold each end of the slinky while a third student moves the slinky from the center to demonstrate the assorted seismic wave movements.

In summary, there were only a few lessons that provided an inquiry-based activity for students. The majority of the activities were instruction driven with a worksheet to complete.

Organizational Differences in Lessons

Most lessons contained an activity which ranged from filling worksheets to designing and developing models. Approximately half of the lessons contained lectures for the teachers.

All groups demonstrated diversity in the range of topics. The topics coded included: fault zones, human interaction, plate tectonics, seismic waves, and landscape topics.

Lesson 3: Students will use a GPS computer program from the Internet to access locations along with data from the plate boundary observation to create a visual model to reflect the velocity and movements of plates. (plate tectonics topic)

Lesson 4: Students will use GPS translation as a method to estimate distances from cities to earthquake centers in the preparation of people and buildings. (human interaction topic)

Lesson 5: Students will learn the concept of elastic rebound and how energy is stored and released and faults to create an earthquake.

Lesson 10: Students will use slinkys as a demonstration for seismic waves, and will help students visualize how seismic waves propagate through the Earth. (seismic wave topic)

Lesson 13: Students will learn how earthquakes can shape and change the landscape around them, creating and destroying mountains and other landscape features. (landscape topic)

Different type activities used in the lessons. The activities were broken down into three types of pedagogical approaches: report style (40 lessons), research-based (34 lessons) and hands-on (16 lessons). The following lessons exhibit one of the three primary types of activities.

Lesson 4: Students will use the Internet to research GPS location and distance estimating features. (university organizational group)

Lesson 12: Students will be given a hands-on activity to demonstrate the movement of plate tectonics. (professional organizational group)

Lesson 20: After reading an article students will be asked to fill in a worksheet answering specific questions. (non-profit organizational group)

Student and teacher centered lessons found in the study. The teacher centered lessons typically provided direct instruction followed by an activity, which represented

31 or 69% of the lessons. The student centered lessons were more inquiry -like, such that the students were asked to develop and design solutions to their situations, which represented 14 or 31% of the lessons.

Lesson 1: Lesson procedures--as students what a glacier is and how it moves, gather questions at the end and compile a list, explain to students that they will work in small groups. Data acquisition--student should be divided into groups, small groups will work together, visit each group and get them started gathering data from the maps. Lab reports--map should be projected in each group should present the answers to their questions and the results of their lab reports to class, lab reports should be graded. (teacher centered)

Lesson 22: Students will be able to understand the basics of how earthquakes work and why they occur through self-guided research on earthquakes. Students will be asked to investigate the importance of high-quality construction in earthquake zones. Students will be asked what they learned and how it can help in being prepared for future earthquakes. (student centered)

In summary, there was diversity within the organizations with regard to topics. In general there were three basic forms of activities found among the organizations.

Grade Appropriateness and Grade Targeting in Lessons

An analysis of great appropriateness of the lessons found that the majority of lessons were grade appropriate for the grade described in the lessons. There were seven (16% of the lessons) exceptions that were labeled as non-grade appropriate. Moreover, five of the seven grade level inappropriate lessons were from the government organizations. This was the only notable trend in the grade appropriateness evaluation. Listed here are some examples of materials that were deemed to be non-grade appropriate.

Mis-advertised grade level of lessons. Two of the lessons were simply mis-advertised, and as a result have been labeled as non-grade appropriate. The first lesson was advertised for 9th through 12th grade, and the second lesson was advertised for grades K through 12. However, in the lessons they described a different grade set for the activity and lesson.

Lesson 2: This activity was designed with a university junior level mineralogy/petrology course in mind.

Lesson 7: This lesson was produced for grades 7 through 12.

Non-grade appropriate content of lessons. Some of the lessons were advertised for grades K through 12, and although the activities and lessons utilize words that are simple enough for high school students to understand, they also utilized terminology and content that may not be suitable for kindergarten nor did they offer any additional guidance for high school level.

Lesson 41: Students will construct and use a seismograph to demonstrate the measurement of earthquakes, intended for all grades. Vocabulary to be taught to students: magnitude, Richter scale, seismograph, mechanical, electrical device, seismic waves, amplitude and additional vocabulary. (Grades K-12 lesson)

Lesson 42: Students will color in a picture of a horizontal fault movement and a vertical fault movement. This is to illustrate both horizontal and other fault movements. (Grades K-12 lesson)

Grade appropriate lessons. The lessons that were considered grade appropriate included lesson materials and/or activities that were developed with the list grade levels in mind. Below are two lessons that demonstrate grade appropriateness as both the content and the terminology are appropriate for the grade range.

Lesson 12: Students will use a paint-by-numbers version of plate boundaries printed on paper. Students are then to color in the pieces and finally cut the pieces out. The puzzle pieces will be used to demonstrate how the plates slide along each other. Students are then asked what they think the world will look like in 100,000 years, 1,000,000 years…etc. (Grades 6-9 lesson)

Lesson 38: Students will mix batter in order to make pancakes. The pancakes will be baked on a griddle in order to demonstrate the creation of cracks and other faults. Specific directions will be given to the student and parents in order to successfully accomplish this activity. Students are the asked to answer questions such as, whether the middle or the edge cools faster? (Grades 1-6 lesson)

In summary, the vast majority of lessons achieved grade appropriateness by targeting students with the intended grade appropriate terminology and activities. The few lessons that did not achieve grade appropriateness status did so by misrepresenting their lessons or not providing ample explanation in the lessons or alternative activities to accommodate the vast grade range advertised.

Chapter 5

DISCUSSION, IMPLICATIONS AND CONSIDERATIONS

NRC Framework Crosscutting Evidence and Themes in Earth Science Materials

This study was conducted to determine if materials found on the internet provide the content of the crosscutting concepts of the *NRC Framework* and the *NGSS*. Three questions were asked researched. To what extent were the crosscutting concepts of the *NRC Framework* present in Earth science teacher materials available on the internet? To what extent were the engineering crosscutting concepts of the *NRC Framework* present in Earth science teacher materials available on the internet? What themes were present in the Earth science teacher materials available on the internet?

Evidence of the Crosscutting Concepts in Science

Quantitative and qualitative analysis were used to evaluate lessons currently found on the internet. The study determined that there was sufficient evidence to state that the Science Crosscutting Concepts of the *NRC Framework* were being incorporated into the lessons. The descriptive analysis indicated all of the lessons demonstrated evidence of the science crosscutting concepts. Each of lessons showed evidence of at least one science crosscutting concept. The qualitative analysis also found that a majority of the lessons demonstrated evidence of the science crosscutting concepts.

The presence of the science crosscutting concepts may resulted from the fact that science standards in place for several decades. This again related to the notion that the science crosscutting concepts were similar to the science standards currently in place. The lessons on the internet were appropriate for the purpose and could be used by teachers.

Evidence of the Crosscutting Concepts in Engineering

The study determined that there was sufficient evidence to state that the engineering Crosscutting Concepts of the *NRC Framework* were not being incorporated into lessons currently available on the internet. The analysis was conducted using the same process as the science crosscutting evaluation. The majority of the lessons either had no evidence at all or just a few of the crosscutting concepts. The qualitative analysis confirmed these results of the quantitative analysis with less than a third of the lessons demonstrating evidence of the engineering crosscutting concepts.

In the past there were no specific engineering standards to build lessons. Until now, the use of engineering concepts was added by coincidence, to add hands-on activities or to increase inquiry-based learning. As a result, there was a difference between the amount of evidence for the science crosscutting concepts and the amount of evidence for the engineering crosscutting concepts. One of the implications for the absence of engineering crosscutting concepts is that teachers are not going to be able to find a large assortment of lessons to use in the classroom that met their needs or the needs of their students. A larger concern is that new teachers may not fully understand the implications of using sub-standard lessons in the classroom.

Application of the Engineering Crosscutting Concepts

Evidence for the application of engineering was provided by the hands-on activities. The least amount of evidence was found for the application of engineering with less than a fourth of the lessons demonstrating some hands-on activity as part of the lesson. Showed a majority of the lessons either had no evidence at all, or just a few of the crosscutting concepts. This quantitative data was again confirmed by the qualitative analysis results which found that less than a tenth of the lessons demonstrated strong evidence of the application of engineering.

Hands-on modeling activities incorporated the use of a physical model, with students engaged in the use of a model, building or designing the model, or any combination thereof. However, the activities were limited in scope. Each of the lesson topics included only a few types of activities. All activities in wave function used a slinky. Fault zones used blocks of wood or styrofoam blocks. It was not enough to simply have students participate in an activity. Lessons developers needed to have the activity drive the students to create a solution to the problem and develop their own conclusions.

The application of engineering analysis was similar to those of the engineering crosscutting results. As with the engineering crosscutting implications, the wider implication is that teachers are not going to be able to find an assortment of lessons to use in the classroom that met their needs or the needs of their students. A larger concern is that new teachers may not fully understand the implications of using sub-standard lessons in the classroom.

ANOVA Results for the Crosscutting Concepts

There was no statistically significant difference among the organizations or the topics with respect to the science crosscutting concepts, engineering crosscutting or the application of engineering. The ANOVA demonstrated the lessons that were developed by the organization groups were created using similar concepts, material and activities. Further reducing content differentiation may be the limited topics covered by the sample of lesson examined, as there were only six topics that were used in the lessons. The lack of variety among lessons may have been the result of building lessons on pre-existing material or on materials considered most common by the developer.

Other Activities in the Lessons

The vast majority of the samples required a reporting activity in which students write a paper, worksheet, or other writing task as part of the overall activity. Reporting was the most widely used activity among all the lessons and was evident in nearly all the lessons. Perhaps the writing activity provided an easier way for teachers to engage in summative or formative assessment than other kinds of activities. Unfortunately, it typically followed a teacher centered lesson. This may reduce the rigor and intrinsic motivation for students to learn.

The next category was identified as a research-based activity, which included students using a computer or a model to further understand a relationship or concept that was part of the lessons. For example, students would be required to use the internet to find answers to questions on a worksheet. For this category, the majority of the lessons were similar to the report activity in that all of the research activity also had a report activity to go with it. Although this form of activity generally provided a greater opportunity for students to come to their own conclusions, it still lacked a student centered lesson.

The hands-on activities were related to both the report style activity and the research-based activity, as they all shared the same samples. This appeared to be set up like a hierarchy. All of the hands-on activities contained a research-based activity which then contained a report-based activity. This made sense and may have contributed to the higher number of crosscutting concepts in the development of these activities in the materials.

Teacher and Student Centered Lessons

The qualitative analysis found that two thirds of the lessons were teacher centered. The majority of the lessons included step-by-step directions for not only the students, but the teachers as well. Several of the lessons included teacher lectures in which the teachers could read directly from the lesson itself to the students. The students were given direct instruction about how to complete a given task assigned by the lesson. The remaining one third of the lessons was student centered. They provided an opportunity for the students to develop and design solutions and provided inquiry-based lessons. In the student centered lessons, students were asked to develop the problem and design a solution. The lessons that were teacher centered were not meeting the standards of the *NRC Framework*, as the new framework emphasizes the practice of science and engineering accomplished through student centered lessons and activities. As a consequence, once again teachers and educators will have a difficult time finding materials that are currently on the internet to be used in the classroom that need student centered an inquiry-based learning. This may be an issue for states and districts that adopt performed based assessments.

Grade Appropriateness in the Lessons

The evaluation found that the majority of the lessons were grade appropriate. The grade appropriate lessons demonstrated that organizations were meeting the needs of those they were targeting by the context of the material, the language of lessons and the activities of the lessons. There was no relationship between the organizations and topics in terms of grade appropriateness of the lessons. The lessons that were not considered grade appropriate appeared to be a higher cognitive level than appropriate for the designated age range. The lessons found on the internet were appropriate for the of the student populations for which they were designed.

Broader Implications

Professional development and training. One implication for education will be the need for teacher professional development and pre-service teacher programs to meet the requirements of the *NGSS* and the newly adopted engineering standards. This may pose a challenge of not only bring current teachers up-to-date, but also finding and training those responsible to implement teacher professional developments. Professional developments need to be created. The professional developments may take place at the school site or be completed at a post-secondary institutions. Pre-service teacher programs will need to develop new training materials and find individuals qualified to teach the new standards. Post-secondary schools will need to determine how to incorporate the new standards into pre-existing classes or develop new ones. Other concerns may include how it would affect the number of credits post-secondary students would take and the additional faculty resources needed.

Engineering and education. There will be a new demand for qualified individuals that are versed in both engineering and education. Engineering educators will be sought after by different groups, organizations and institutions. Engineering educators will be needed for assisting in the development of materials and training on the *NGSS*. They could serve in liaison positions between engineers, industry and education specialists in the development of lesson, curricula, training and other materials to support the new standards. The *NGSS* and the adoption of the engineering standards will provide students with an opportunity to engage in engineering focused concepts. The new engineering standards may also provide students with the crosscutting concepts to demonstrate the tie between science and engineering. This opportunity may provide students with a better understanding of engineering and the function of engineers. The addition of the engineering standards may help to support engineering programs at post-secondary schools by providing students a basic introduction to engineering concepts.

Materials for the new standards. With the onset of new standards comes the need for new and up-dated materials. Materials include: lessons plans, text books (K-12 and post-secondary), assessments and supplies. For school districts it is not just the teachers that need to be up-dated, but the classroom resources they use. New text books for K-12 must be developed, to incorporate the *NGSS* costing districts and states thousands of dollars. Text books for post-secondary schools also need to be developed. Current lesson plans require revising and new ones will need to be created to meet the new standards. In addition to books and lessons, the creation of assessments will be required. The development of new assessments will be needed for school districts and states that administer standardized exams. New assessments and text books will require funds and resources from different government agencies and other stake holders. The assessments and text books need to be developed by knowledgeable specialists. Additional assessments will be required for teachers to use as they require for assessing in the classroom. Classroom laboratory equipment needs to be purchased to assist in providing student hands-on activities and to supplement lessons to support the *NGSS*. The new equipment may also need to be part of the training for the teachers and pre-service teachers in their use and integration of the new standards. The new materials and equipment will create a need in industry to design and develop in accordance to the needs of the *NGSS*. With the development and acquisition of the materials and supplies will be the need to pay for them. This would support continuing issues with funding from the public, government agencies and politicians.

Recommendations

Current Lessons

It is important to make sure that the materials found by teachers, students and the public met the standards associated with the *NRC Framework*. More attention should be paid to evaluating items to ensure that they meet the expectation set forth by the *NRC Framework* and Standards and to remove those that cannot be updated to the new standards. Those lessons without engineering concepts need to be revised to include them. Increased student centered and inquiry-based learning, activities should also be incorporated into the lessons. When revising and updating current lessons, the activities added should draw on a wider variety of examples. This may help in reduce redundancies of activities currently used. During the search process for samples to be used in the research, many dead links were discovered and many more went to items that were unrelated to the search itself. Organizations needed to make sure what they had available on the internet is up to date and relevant to the scope of the audience it is attempting to reach. As the lessons lacked any specific assessments, developers need to make sure that the materials supply an assessment that could be used with the lesson or activity.

Creating New Lessons

The results of the study indicated a need for materials to be created that meet the standards that were set forth by the *NRC Framework*. In order to assist in developing materials that were inclusive of the crosscutting concepts, developers need to become educated and proficient in understanding the *NGSS* along with the crosscutting concepts of the *NRC Framework*. Developers need to be careful that they did not diminish the rigor of their content in order to simply to meet the standards. Developers need to use the standards along with the crosscutting concepts to develop materials that benefited teachers and students, along with the general public in their understanding of science and engineering. As the *NRC Framework* included engineering standards, the use of engineering practices needed to be incorporated into newly developed lessons. One method for helping to increase the rigor and the content of the engineering crosscutting concepts in lessons is to increase the amount of activities, specifically hands-on modeling activities, in lessons. Students needed to be challenged to design and utilize inquiry-based lessons to develop solutions and practices using engineering concepts. As results had shown, materials that contained hands on modeling activities provided much better evidence of the crosscutting concepts as they related to engineering.

Newly developed lessons should step back from the idea of creating a “one size fits all” approach to developing lessons when considering grade appropriateness. A challenge to lesson developers may be creating lessons suitable for different grade ranges, by approaching smaller grade ranges as described in the *NRC Framework*. Lesson developers would then be able to utilize language and topics more suitable for students. Lessons should to be developed using student centered practices. It is important for students to be able to practice science and engineering. Lesson must be inquiry-based, allowing students to discover and develop their own solutions while coming to their own understanding of the problem. The use of lectures not only reduces the teacher's ability to be creative in their teaching, but affects the students as well.

Activities

The research found that there were a limited number of activities that were used in the different lessons. Lessons that related to fault zone topics typically used styrofoam modeling activities. Activities could use other items that create friction to demonstrate the slipping of faults such as sandpaper and even soap and wood. When demonstrating concepts of seismic wave functions, there was the repetitive use of slinkys to demonstrate this concept. There were no other examples, but several different variations of the use of a Slinky. Seismic waves are another concept that could use additional examples to demonstrate the movement and propagation of seismic waves. When considering the topic of human involvement, there were limited examples used to demonstrate this concept. The activity that was found in all demonstrations of this concept included the building of a model city and then moving the foundation to represent an earthquake in order to observe the consequences of earthquakes on buildings. Although these demonstrations all showed a representation of their assorted concepts, they were limited in their number and more so in their diversity. The quantity of activities was limited to a few per topic and they demonstrated no differentiation within the topics. Effort could be made to further increase the diversity of these activities and apply them to the materials to help reinforce the concepts and build a deeper understanding while increasing the crosscutting concepts as they related more specifically to engineering.

Future Considerations

Evaluation Instrument

The development of the material evaluation rubric used in this study may allow other researchers the opportunity to evaluate other materials in other fields as they related to the crosscutting concepts of the *NRC Framework* as well as the *NGSS*. The instrument could be used for any science field in order to help enhance, design, or update current materials to meet the crosscutting concepts for the *NRC Framework*. The material evaluation rubric is also a tool that could be used in evaluating current materials as to whether or not they met the new standards.

Future Studies

This study did represent an opportunity to expand upon and examine other content areas as it related to materials and the *NGSS*. With additional resources and time, a more comprehensive study could be done to look at a much broader range of samples to include not only internet samples but also that of textbooks and other teacher acquired materials. The study could also be conducted to compare content areas, along with the different sources of materials. Such as study would provide a much richer overview of the extent to which the crosscutting concepts were being incorporated into lessons.

New Materials

The use of this evaluation instrument is a tool that could be used in the evaluation of current materials, but could also be used in the evaluation of materials recently developed. The evaluation instrument could be used as a template for the development of future lessons. This study demonstrated the need to make sure that materials created were meeting the needs of the *NRC Framework*, *NGSS*, and schools and school districts nationwide. In the consideration of this study, developers had an opportunity and the ability to evaluate their content and material structure for future students and teachers. Material that is not made current with the new standards my find issues with funding agencies for not providing usable items.

Limitations

The greatest limitation of this study was that generalization was not possible. This research only had the opportunity to look at a small group of material due to lack of resources, limited content area and time. Thus, it is difficult to identify to what extent the *NRC Framework* crosscutting concepts were being incorporated into other material on the Internet, much less all materials in general. Additional concerns included the fact that there was only a single evaluator looking at all the material. This could be a source of bias in the evaluation. In order to reduce this, inter rater reliability would have to be calculated using another evaluator.

Summary

As more and more states adopt the *NGSS,* the need for educational materials to provide content that meet the requirements of the new standards will increase. This study demonstrated that current materials, although they exhibit the science crosscutting concepts, lack those of the engineering crosscutting concepts. Hands-on modeling activities need to be designed and developed and incorporated into educational materials to compensate for their absences in the materials in this study. In order to help develop materials that met the new standards, the use of an instrument such as the one developed for this study could be used to help identify areas of need and improvement not only in current educational material, but future educational material too.

REFERENCES

Accreditation Board for Engineering & Technology (2011). *Criteria for Accrediting Engineering Programs*. Baltimore, MD: Engineering Accreditation Commission.

American Association for the Advancement of Science (2009). *Benchmarks for science literacy*. New York, NY: Oxford University Press.

Bloom, L. B., Hasting, J. T., & Madaus, G. F. (1971). *Handbook on formative and summative evaluation of student learning*. New York: McGraw-Hill.

Common Core Standards Initiative (2010). *CCSS for Literacy in History/Social Studies, Science and Technical Subjects*. Washington, DC: National Governors Association Center for Best Practices, Council of Chief State School Officers.

Confrey, J., & Stohl, V. (2004). *On evaluating curricular effectiveness: Judging the quality of K-12 mathematics evaluations*. National Academies Press.

Crocker, L. M., & Algina, J. (2006). *Introduction to classical and modern test theory*. Wadsworth Pub Co.

Dick, A., Rick, W., Waters, T., & State of California, Department of Corrections and Rehabilitation (2009). *Curriculum evaluation*. Chico, CA: California State University.

Finch, C. R., & Crunkilton, J. R. (1999). *Curriculum development in vocational and technical Education: Planning, content, and implementation* (5th ed.). Needham Heights, MA: Allyn and Bacon.

Gersten, R., Chard, D. J., Jayanthi, M., Baker, S. K., Morphy, P., & Flojo, J. (2009). Mathematics instruction for students with learning disabilities: A meta-analysis of instructional components. In *Review of Educational Research, 79(3)* (pp. 1202-1242).

Greenseid, L., Johnson, K., & Lawrenz, F. (2008). A citation analysis of the influence of the ate, cetp, lsc, and msp-reta evaluations on the stem education and evaluation fields. In *Beyond Evaluation Use*.

Hall, G. E., & Loucks, S. F. (1977). A developmental model for determining whether the treatment is actually implemented. In *American Educational Research Journal, 14(3)*(pp. 263-276). American Educational Research Association.

Keiser, J. C., Lawrenz, F., & Appleton, J. (2004). *Evaluation of materials produced by the ATE program*. National Science Foundation.

Keiser, J. C., Lawrenz, F., & Appleton, J. (2004). Technical education curriculum assessment. In *Journal of Vocational Education Research, 29(3)* (pp. 181-194).

Kimpston, R. D. (1985). Curriculum fidelity and the implementation tasks employed by teachers: a research study. In *Journal of Cirriculum Studies, 17(2)* (pp. 185-195).

McTighe, J., & Wiggins, G. P. (1998). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.

Mills, S. C., & Ragan, T. J. (2000). A tool for analyzing implementation fidelity of an integrated learning system. In *Educational Technology research and development, 48(4)* (pp. 21-41).

National Research Council. (2011). *A NRC Framework: Practices, crosscutting concepts, and core ideas*. Washington, D.C: The National Academies Press.

National Research Council (1996). *NSES*. Washington, DC: The National Academy Press.

National Research Council (2010). *Standards for K-12 engineering education?* Washington, D.C: The National Academies Press.

O'Donnell, C. L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K–12 curriculum intervention research. In *Review of Educational Research 78(1)* (pp. 33-84).

Robrecht, L. C. (1995). Grounded theory: Evolving methods. *Qualitative Health Research*, *5*(2), 169-177.

Schwab, P. (2011). *Analysis of chapter 4 exams from the arizona edition of the algebra 2 book, published by mcdougal littell using the specification table method*. Arizona State University, Tempe, AZ: Unpublished manuscript.

Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2008). *Educating engineers: Designing for the future of the field*. San Francisco, CA: Jossey-Bass.

Stern, P. N. (1980). Grounded theory methodology: Its uses and processes. *Journal of Nursing Scholarship*, *12*(1), 20-23.

Strauss, A., & Corbin, J. (1994). Grounded theory methodology. *Handbook of qualitative research*, 273-285.

Wiggins, G., McTighe, J., & Association for Supervision and Curriculum Development (1998).*Understanding by design*. Alexandria, VA:

Yarnall, L. (2010). *The ATE Suitability Inventory: A tool for analyzing features of workforce education instructional materials*. SRI International.

Chism, N., Douglas, E., & Hilson, W. J. (2008). Qualitative Research Basics: A Guide for Engineering Educators. *Rigorous Research in Engineering Education*.

Erickson, F., & Michigan State University. (1985). *Qualitative methods in research on teaching*. East Lansing, Mich: Institute for Research on Teaching.

National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century*. Washington, D.C: National Academies Press.

APPENDIX A

MATERIAL EVALUATION INSTRUMENT

Document Rubric for the Evaluation of Teacher Lesson Plan Materials with Respect to the Next Generation Science Standards and the Engineering Crosscutting Concepts

____

Title of Document

____

Organization

____

Intended Grade Level

Version 9 Page 1

Summary Findings:

	A	B	C
Patterns			
Cause and Effect			
SPQ			
Systems			
Energy and Matter			
Structure and Function			
Stability and Change			

A: Evidence of the CC

B: Evidence of the engineering CC

C: Evidence of application of the engineering CC

Grade Appropriate? [ ]

Version 9 Page 2

Document Title:

1. Rubric for the NGSS Crosscutting Concept of: *Patterns.* Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.*

A. Is there evidence of the NGSS crosscutting concept in the document? Yes No

What extent is the crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

B. Is there evidence of the NGSS engineering crosscutting concept in the document? Yes No

What extent is the engineering crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

C. Is there evidence of application of the NGSS engineering crosscutting concepts in the document? Yes No

What extent is there application of the NGSS engineering crosscutting concepts in the document?

1	2	3	4	5
None				consistently

Justification:

2. Rubric for the NGSS Crosscutting Concept of: *Cause and effect: Mechanism and explanation.* Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.*

A. Is there evidence of the NGSS crosscutting concept in the document? Yes No

What extent is the crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

B. Is there evidence of the NGSS engineering crosscutting concept in the document? Yes No

What extent is the engineering crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

C. Is there evidence of application of the NGSS engineering crosscutting concepts in the document? Yes No

What extent is there application of the NGSS engineering crosscutting concepts in the document?

1	2	3	4	5
None				consistently

Justification:

:

3. Rubric for the NGSS Crosscutting Concept of: *Scale, proportion, and quantity*. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.*

A. Is there evidence of the NGSS crosscutting concept in the document? Yes No

What extent is the crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

B. Is there evidence of the NGSS engineering crosscutting concept in the document? Yes No

What extent is the engineering crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

C. Is there evidence of application of the NGSS engineering crosscutting concepts in the document? Yes No

What extent is there application of the NGSS engineering crosscutting concepts in the document?

1	2	3	4	5
None				consistently

Justification:

4. Rubric for the NGSS Crosscutting Concept of: *Systems and system models*. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.*

A. Is there evidence of the NGSS crosscutting concept in the document? Yes No

What extent is the crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

B. Is there evidence of the NGSS engineering crosscutting concept in the document? Yes No

What extent is the engineering crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

C. Is there evidence of application of the NGSS engineering crosscutting concepts in the document? Yes No

What extent is there application of the NGSS engineering crosscutting concepts in the document?

1	2	3	4	5
None				consistently

Justification:

5. Rubric for the NGSS Crosscutting Concept of: *Energy and matter: Flows, cycles, and conservation.* Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.*

A. Is there evidence of the NGSS crosscutting concept in the document? Yes No

What extent is the crosscutting concept present in the document?

1 None	2	3	4	5 consistently

Justification:

B. Is there evidence of the NGSS engineering crosscutting concept in the document? Yes No

What extent is the engineering crosscutting concept present in the document?

1 None	2	3	4	5 consistently

Justification:

C. Is there evidence of application of the NGSS engineering crosscutting concepts in the document? Yes No

What extent is there application of the NGSS engineering crosscutting concepts in the document?

1 None	2	3	4	5 consistently

Justification:

6. Rubric for the NGSS Crosscutting Concept of: *Structure and function.* The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.*

A. Is there evidence of the NGSS crosscutting concept in the document? Yes No

What extent is the crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

B. Is there evidence of the NGSS engineering crosscutting concept in the document? Yes No

What extent is the engineering crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

C. Is there evidence of application of the NGSS engineering crosscutting concepts in the document? Yes No

What extent is there application of the NGSS engineering crosscutting concepts in the document?

1	2	3	4	5
None				consistently

Justification:

7. Rubric for the NGSS Crosscutting Concept of: *Stability and change*. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.*

A. Is there evidence of the NGSS crosscutting concept in the document?
Yes No

What extent is the crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

B. Is there evidence of the NGSS engineering crosscutting concept in the document? Yes No

What extent is the engineering crosscutting concept present in the document?

1	2	3	4	5
None				consistently

Justification:

C. Is there evidence of application of the NGSS engineering crosscutting concepts in the document? Yes No

What extent is there application of the NGSS engineering crosscutting concepts in the document?

1	2	3	4	5
None				consistently

Justification:

8. Is there evidence of grade appropriate material in the document?
Yes No

Justification:

*Descriptions of the crosscutting concepts are quoted from the National Research Council. (2011). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, D.C: The National Academies Press, p. 84.

APPENDIX B

EXAMPLES OF ORGANIZATIONS IN THE ORGANIZATIONAL CATEGORIES

Examples of organizations in the organizational categories

Organizations	Examples (limited list)
Commercial Organizations (CO)	Discovery Channel, National Geographic, Education World, Holt McDougal Publishing Company
Non-Profit Organizations (NO)	Public Broadcasting Service, Earth Exploration Toolbook, Digital Library for Earth System Education, Center for Innovation in Engineering and Science Education
Government Organizations (GO)	US Geological Survey, Southern California Earthquake Center, New Mexico Bureau of Geology & Mineral Resources, National Aeronautics and Space Administration
Professional Organizations (PO)	Geological Society of America, American Geophysical Union, American Geosciences Institute, Seismological Society of America
University Organization (UO)	Northwestern University, University of California San Diego, California Institute of Technology, Rice University, Arizona State University, Massachusetts Institute of Technology

APPENDIX C

NSF EARTHSCOPE GRANT REQUEST LETTERS

Hello,

My name is Patrick Schwab, I am a Graduate Research Associate with the EarthScope National Office at Arizona State University. I am making an archive of K-12 teacher materials and resources that are being provided to teachers by EarthScope projects and programs. I am contacting you because you have been identified through the National Science Foundation awarded grant database as being an active program using EarthScope data or resources. I'm asking if you participate in K-12 teacher workshops or in-services that you provide me with the materials given to teachers during these events so that I may compile the archive. If you have physical materials please mail them to me at the address provided, or if you have electronic copies you may email them to me as well. If your resources and materials are online, please send me the web address. Your attention to this matter is greatly appreciated and will help to provide resources to teachers and educators.

Arizona State University
ATTN: Patrick Schwab
PO Box 876004
Tempe, AZ 85287-6004

Thank you for your help and assistance,
Patrick

Hello again,

Once again, my name is Patrick Schwab, and I am a Graduate Research Associate with the EarthScope National Office at Arizona State University. I am trying making an archive of K-12 teacher materials and resources that are being provided to teachers by EarthScope projects and programs. I am contacting you because you have been identified through the National Science Foundation awarded grant database as being an active program using EarthScope data or resources and I did not hear back from you in my first attempt. I'm asking if have made any K-12 teacher materials that you let me know, or if you do not have or participate in such endeavors that you let me know that as well.

If you have physical materials please mail them to me at the address provided, or if you have electronic copies you may email them to me as well. If your resources and materials are online, please send me the web address. Your attention to this matter is greatly appreciated and will help to provide resources to teachers and educators.

Arizona State University
ATTN: Patrick Schwab
PO Box 876004
Tempe, AZ 85287-6004

Thank you for your help and assistance,
Patrick

APPENDIX D

DESCRIPTIVE ANALYSIS SUMMARY TABLES FOR THE ORGANIZATION CATEGORY

Descriptive Statistics Summary for the Organization Category

Concept Category	CO		GO		NO		PO		UO	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
P-S	3.14	1.07	3.29	0.76	3.60	0.83	3.50	0.58	3.50	1.09
P-E	1.71	1.25	1.00	0.00	1.13	0.52	1.00	0.00	1.08	0.29
P-A	1.43	1.13	1.00	0.00	1.13	0.52	1.00	0.00	1.00	0.00
CE-S	3.14	1.35	3.14	1.21	3.33	1.45	3.25	0.96	3.50	1.38
CE-E	1.86	1.46	1.57	1.13	1.47	0.83	1.50	1.00	1.58	0.90
CE-A	1.43	1.13	1.00	0.00	1.27	0.59	1.25	0.5	1.42	0.90
SPQ-S	2.86	0.69	3.14	0.69	3.33	0.90	3.25	0.96	3.42	1.16
SPQ-E	1.43	1.13	1.71	1.25	2.13	1.46	2.00	1.15	2.25	1.48
SPQ-A	1.29	0.76	1.71	1.25	1.60	0.99	2.00	1.15	1.58	1.08
SSM-S	2.43	0.98	2.57	0.79	2.47	1.06	2.75	0.96	2.92	1.31
SSM-E	1.29	0.76	1.43	1.13	1.60	0.83	1.00	0.00	1.50	0.80
SSM-A	1.29	0.76	1.29	0.76	1.20	0.41	1.00	0.00	1.25	0.62
EM-S	3.00	1.29	3.14	1.21	3.33	1.29	3.75	1.26	3.67	0.98
EM-E	1.71	1.25	1.71	1.25	1.87	1.06	1.75	1.50	2.17	1.34
EM-A	1.43	1.13	1.43	0.79	1.53	1.06	1.25	0.50	1.58	1.00
SF-S	2.29	1.38	2.00	1.00	2.27	1.10	3.00	0.82	3.00	1.35
SF-E	1.86	1.21	1.29	0.76	1.33	0.72	1.25	0.50	1.33	0.49
SF-A	1.29	0.76	1.29	0.76	1.20	0.41	1.00	0.00	1.25	0.62
SC-S	3.43	1.13	2.86	0.69	3.67	0.98	3.50	1.73	3.83	1.40
SC-E	1.43	0.79	1.14	0.38	1.13	0.35	1.50	1.00	1.17	0.39
SC-A	1.29	0.76	1.00	0.00	1.07	0.26	1.00	0.00	1.17	0.39

Note. P-S = Patterns: Science Crosscutting Concepts; P-E = Patterns: Engineering Crosscutting Concepts; P-A = Patterns: Application of the Engineering Crosscutting Concept; CE-S = Cause and Effect: Science Crosscutting Concepts; CE-E = Cause and Effect: Engineering Crosscutting Concepts; CE-A = Cause and Effect: Application of the Engineering Crosscutting Concept; SPQ-S = Scale, Proportion and Quantity: Science Crosscutting Concepts; SPQ-E = Scale, Proportion and Quantity: Engineering Crosscutting Concepts; SPQ-A = Scale, Proportion and Quantity: Application of the Engineering Crosscutting Concept; SSM-S = Systems and Systems Models: Science Crosscutting Concepts; SSM-E = Systems and Systems Models: Engineering Crosscutting Concepts; SSM-A = Systems and Systems Models: Application of the Engineering Crosscutting Concept; EM-S = Energy and Matter: Science Crosscutting Concepts; EM-E = Energy and Matter: Engineering Crosscutting Concepts; EM-A = Energy and Matter: Application of the Engineering Crosscutting Concept; SF-S = Structure and Function: Science Crosscutting Concepts; SF-E = Structure and Function: Engineering Crosscutting Concepts; SF-A = Structure and Function: Application of the Engineering Crosscutting Concept; SC-S = Stability and Change: Science Crosscutting Concepts; SC-E = Stability and Change: Engineering Crosscutting Concepts; SC-A = Stability and Change: Application of the Engineering Crosscutting Concept; GA = Grade Appropriate; CO = Commercial Organizations; NO = Non-Profit Organizations; GO = Government Organizations; PO = Professional Organizations; UO = University Organizations.

APPENDIX E

DESCRIPTIVE ANALYSIS SUMMARY TABLES FOR THE TOPICS CATEGORY

Descriptive Statistics Summary for the Topics Category

Concept	FT		HT		LT		PT		VT		WT	
Category	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
P-S	3.14	0.90	3.31	0.95	3.83	0.98	3.75	0.89	4.00	1.00	3.13	0.64
P-E	1.00	0.00	1.38	0.96	1.33	0.82	1.00	0.00	1.00	0.00	1.13	0.35
P-A	1.00	0.00	1.23	0.83	1.33	0.82	1.00	0.00	1.00	0.00	1.00	0.00
CE-S	4.00	1.15	3.31	1.18	3.67	1.37	2.38	1.51	4.00	1.00	3.13	1.13
CE-E	2.29	1.38	1.54	1.13	1.33	0.82	1.25	0.71	1.33	0.58	1.63	0.74
CE-A	1.71	1.11	1.23	0.83	1.33	0.82	1.13	0.35	1.00	0.00	1.25	0.46
SPQ-S	3.57	0.98	3.00	0.71	3.00	1.26	3.38	1.06	3.33	1.15	3.38	0.74
SPQ-E	3.14	1.57	1.23	0.83	1.50	1.22	2.13	1.25	2.67	1.53	2.13	1.36
SPQ-A	2.57	1.27	1.15	0.55	1.50	1.22	1.75	1.04	1.00	0.00	1.63	0.92
SSM-S	3.29	0.95	2.23	0.93	2.00	1.26	2.88	0.99	3.67	0.58	2.50	0.93
SSM-E	2.43	0.98	1.23	0.60	1.33	0.82	1.13	0.35	1.00	0.00	1.50	0.93
SSM-A	1.86	0.90	1.15	0.55	1.00	0.00	1.00	0.00	1.00	0.00	1.25	0.46
EM-S	3.86	0.90	2.85	1.14	3.33	1.21	3.63	1.41	2.33	0.58	4.00	0.93
EM-E	3.00	1.15	1.38	0.96	2.00	1.26	1.50	1.07	1.67	1.15	2.13	1.25
EM-A	2.29	1.11	1.23	0.83	1.50	1.22	1.13	0.35	1.00	0.00	1.75	1.04
SF-S	2.57	0.53	1.77	1.09	3.00	1.41	3.38	0.92	3.67	1.53	1.88	0.83
SF-E	1.86	0.90	1.46	0.97	1.17	0.41	1.50	0.76	1.00	0.00	1.13	0.35
SF-A	1.71	0.95	1.15	0.55	1.00	0.00	1.25	0.46	1.00	0.00	1.13	0.35
SC-S	3.57	0.98	3.38	1.19	4.17	0.75	4.13	0.99	3.33	2.08	2.75	1.04
SC-E	1.43	0.53	1.23	0.60	1.17	0.41	1.25	0.71	1.00	0.00	1.13	0.35
SC-A	1.29	0.49	1.15	0.55	1.17	0.41	1.00	0.00	1.00	0.00	1.00	0.00

Note. P-S = Patterns: Science Crosscutting Concepts; P-E = Patterns: Engineering Crosscutting Concepts; P-A = Patterns: Application of the Engineering Crosscutting Concept; CE-S = Cause and Effect: Science Crosscutting Concepts; CE-E = Cause and Effect: Engineering Crosscutting Concepts; CE-A = Cause and Effect: Application of the Engineering Crosscutting Concept; SPQ-S = Scale, Proportion and Quantity: Science Crosscutting Concepts; SPQ-E = Scale, Proportion and Quantity: Engineering Crosscutting Concepts; SPQ-A = Scale, Proportion and Quantity: Application of the Engineering Crosscutting Concept; SSM-S = Systems and Systems Models: Science Crosscutting Concepts; SSM-E = Systems and Systems Models: Engineering Crosscutting Concepts; SSM-A = Systems and Systems Models: Application of the Engineering Crosscutting Concept; EM-S = Energy and Matter: Science Crosscutting Concepts; EM-E = Energy and Matter: Engineering Crosscutting Concepts; EM-A = Energy and Matter: Application of the Engineering Crosscutting Concept; SF-S = Structure and Function: Science Crosscutting Concepts; SF-E = Structure and Function: Engineering Crosscutting Concepts; SF-A = Structure and Function: Application of the Engineering Crosscutting Concept; SC-S = Stability and Change: Science Crosscutting Concepts; SC-E = Stability and Change: Engineering Crosscutting Concepts; SC-A = Stability and Change: Application of the Engineering Crosscutting Concept; GA = Grade Appropriate; VT = Topics that revolve around volcanic influence on earthquakes; WT = Topics that revolve around seismic waves; FT = Topics that revolve around fault zones; PT = Topics that revolve around plate tectonics; HT = Topics that revolve around human interaction; LT = Topics that revolve around the landscape.