Preparing Educators to Employ Design-Based Engineering Practices in K-12 Science

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ABSTRACT

PREPARING EDUCATORS TO EMPLOY
DESIGN-BASED ENGINEERING PRACTICES IN K-12 SCIENCE

By James S. Carlson

The purpose of this study was to characterize a methodological framework for preparing science educators to implement design-based engineering practices to *intentionally* teach targeted science content. Using a modified Delphi the study looked to answer the following research questions (RQs): RQ1: How should teacher educators prepare K-12 pre-service science teachers to *define engineering* problems as one of eight *NGSS* practices all students should acquire through science education?, RQ2: How should teacher educators prepare K-12 pre-service science teachers to *design engineering solutions* as one of eight *NGSS* practices all students should acquire through science education? and , RQ3: How should teacher educators prepare K-12 pre-service science teachers to intentionally teach targeted science content using their newly acquired abilities to define engineering problems and design engineering solutions? During Round 1 a panel of 20 (8 science and 12 technology) education experts responded to 5 open-ended questions that focused on identifying the competencies and instructional strategies used to prepare K-12 preservice science teachers to intently teach science using engineering design. Each question resulted in identifying approximately 50 themes per question. These themes were then used to construct the Round 2 Questionnaire. During Round 2 panelists reached agreement on 283 characteristics of a framework for preparing future science educators. In Round 3, panelists were sent 87 contested Round 2 items. Results of the Round 3 data analysis indicted an additional 31 framework characteristics. The results of this study identify the essential characteristics of a methodological framework that can serve to prepare science educators on the implementation of design-based engineering practices that *intentionally* teach targeted science content.

GENERAL AUDIENCE ABSTRACT

PREPARING EDUCATORS TO EMPLOY DESIGN-BASED ENGINEERING PRACTICES IN K-12 SCIENCE

By James S. Carlson

The purpose of this study was to characterize a methodological framework for preparing science educators to implement design-based engineering practices to *intentionally* teach targeted science content. The rationale for this research was the *Next Generation Science Standards* necessitate science use engineering practices to teach K-12 science content. According to the National Research Council the implementation of engineering practices will take shape in the form of engineering design. To date science education has focused primarily on defining the content of science education at the expense of its application (NRC, 2013, p.2). Furthermore, studies have shown professional development continues to prepare science teacher in the use of scientific inquiry. This study utilized a modified Delphi and focused on answering the question of how teacher educators should prepare pre-service K-12 science teachers to teach the practice of engineering design to intentionally teach targeted science content. The results of this study identify the essential characteristics of a methodological framework that can serve to prepare science educators on the implementation of design-based engineering practices that *intentionally* teach targeted science content.

DEDICATION

I dedicated this dissertation to my parents, who have always told me to finish what I start.

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CHAPTER I

Globalization, progress in the sciences, technological advances, and education research, among other factors, have motivated a need for reform in K-12 science education and in April 2013, through the collaborative efforts of the National Research Council (NRC), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and Achieve, the *Next Generation Science Standards* (*NGSS)* (NGSS Lead States, 2013) were released. The *NGSS* proposes a new direction for science education focusing on the core principles of science along with an emphasis on the practices that support them. Prior to this publication, scientific inquiry was the signature teaching pedagogy of science education as evidenced in publications such as the *Benchmarks for Science Literacy* (*Benchmarks)* (AAAS 1993) and the *National Science Education Standards* (*NSES*) (NRC, 1996). For example according to the National Research Council (NRC) (1996):

> Scientific inquiry refers to the ways in which scientists study the natural world and propose explanations based on evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (p. 23)

The rationale for focusing on scientific inquiry in the classroom was the perception that it would create knowledge of the natural world by engaging students in scientific activities (NRC, 1996, p. 23). However, research in the United Kingdom on how students understand the nature of science and the relationship it has with society has shown that when scientific inquiry is the exclusive focus of science education, students develop a narrow and limited perspective that science exists solely as a body of knowledge (Driver, Leach, Millar, & Scott, 1996). The NRC attributes this largely to the complexity of learning to apply practice of scientific inquiry and insufficient methods to accomplish this. Specifically, research suggests that scientific inquiry alone does not provide students with a background in how science functions in actuality (Millar & Driver, 1987). Teaching methods around scientific inquiry have focused almost exclusively on the methods of science and the recall of science facts rather than on how science operates in the real world (Bybee, 2013; NRC, 2012). These discoveries have lead the NRC to the development of new standards for implementing teaching and learning strategies that shift the focus towards using inquiry practices to teach science and move away from relying exclusively on scientific inquiry. The intent is to provide students not only with the knowledge of science, but also with the means to apply it to solving real-world problems.

In July of 2012, the NRC published *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (Framework)* (NRC, 2012). This publication presents proficiency standards reflecting the science and engineering knowledge-base that all K-12 students should acquire to be considered scientifically literate and good consumers of scientific information. The purpose of these standards is to educate and engage K-12 students with the foundational knowledge of science and engineering with the expectation that students will consider these areas when pursuing careers paths (NRC, 2012, p. 10). The preliminary investigation of the *Framework* identified K-12 science students' lack of fundamental knowledge of science, engineering, technology, and mathematics (NRC, 2012, p. 1). The NRC proposes that the most likely cause is the current structure of K-12 science education. Content is not systematically organized throughout the student's experience and students are not encouraged to make connections to prior knowledge (NRC 2012, p. 1). The NRC also supports that science education to date has focused too heavily on creating a breadth of science knowledge rather than depth and therefore fails to provide students with opportunities to engage in real world science (NRC, 2012, p. 1). The NRC vision was to address these concerns in the new standards.

The *NGSS* proposes a new direction for science education focused on the core principles of science and the practices that support them. A key change is the introduction of engineering design practices into the standards. The NRC (2012) states, “We are convinced that engagement in the practices of engineering design is as much a part of learning science as engagement in the practices of science” (p.12). What is evident in the *NGSS* is a shift from scientific inquiry to that of the practice of inquiry. The *NGSS* argues that inquiry is only one element of the scientific process and that expanding to the teaching of science and engineering practices would enrich the learning of science (NGSS Lead States, 2013). Furthermore the *NGSS* describes how integrating these elements would support student understanding of science. To advance the practices of science, the position of engineering in science has been elevated “…to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines” (NGSS Lead States, 2013, Introduction p. xiii). The rationale for the inclusion of engineering is to engage students in the practices of science and provide experiential learning of science as it is applied to real-world problems (NRC 2012, p. 2). When scientific inquiry is the exclusive focus of education at the expense of science application, students develop the narrow and limited perspective that science exists only as a body of knowledge. This new pedagogical outlook intends to have students create an understanding of science rather than viewing and memorizing science as facts to be learned.

The integration of engineering practices is not a new idea in the teaching of science. Prior documents such as the *Benchmarks* (1993) and *NSES* (1996) also emphasized the value of engineering. At that time both of these documents revolutionized science education teaching and learning and set the stage for establishing connections between the disciplines of science, mathematics, and technology. The *Benchmarks* sought to determine the optimal substance and character of science education, focusing on how each discipline might complement the other (AAAS, 1993). The *NSES* (1996) influenced science education stakeholders by providing guidance in curriculum development. The *NSES* was unique because it provided examples of what science should look like in the classroom (NRC, 1996, p. 16). It was in this document that science teaching refocused on the teaching pedagogy of scientific inquiry. It concentrated on asking the question "how" rather than "why". The *Benchmarks* and the *NSES* identified the content of science education and focused on a need to make connections between the disciplines. The *NGSS* builds on this philosophy and recognizes that the practice of inquiry builds students' knowledge and usage of the STEM disciplines.

The implementation of engineering practices in science education according to the NRC will take shape in the form of teaching students engineering design (NRC, 2012, p. 42). The *NGSS* identifies eight core practices essential for all K-12 students. These practices are highlighted in the first dimension (scientific and engineering practices) of the standards and focus on how the procurement of scientific knowledge requires the development of both science knowledge and skills. The eight core practices of science and engineering emphasized in the *NGSS* (2013b) are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking

6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information. (p. 48)

The objective of each of these practices intends to promote, extend, and/or enhance student learning by developing students' ability to use these skills in supporting and demonstrating their understanding of science and engineering (NRC, 2012, p. 49). The intent of integrating science and engineering practices in the *NGSS* is to provide science educators with guidance on how they can enhance their teaching to better fit the new standards. It allows for students to be engaged in the process of science and develops students' ability to acquire problem-solving skills. Although engineering practices are implied throughout the eight practices it is specifically addressed in practices 1 and 6.

The first practice of asking questions (for science) and defining problems (for engineering) focuses on helping students to understand how scientific knowledge develops (NGSS Lead States, 2013b, p.48). From the engineering lens, the standard describes how students should possess the ability to define the problem as relevant to technology and applications of the science (NGSS Lead States, 2013b, p.54). According to the *NGSS* (2013b) engaging students in the process of defining engineering problems enhances students' abilities in the practice of scientific questioning. As presented, Practice 1 makes no connection to the practice of engineering design. It is not until Practice 6 that engineering design is addressed. Practice 6 emphasizes students' ability to develop explanations (for science) and design solutions (for engineering) (NGSS Lead States, 2013b, p. 60). As defined in the *NGSS*, engineering design is a systematic process for solving engineering problems (NGSS Lead States, 2013b, p. 60). As Practice 1 attempts to build science skills through the use of design-based engineering practices, Practice 6 focuses on engaging students in systematic processes (NGSS Lead States, 2013b, p. 60). The intent of including the engineering practices of defining problems and designing solutions in the *NGSS* is not to teach students engineering or engineering design, rather the goal is to utilize design-based engineering practices to engage students in activities that will enhance their understanding and application of science (NGSS Lead States, 2013b, p. 3).

The NRC states; “We use the term engineering in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems” (NRC, 2012, p. 11). The *NGSS* (2013b) identifies three design-based engineering practices: (1) define, (2) optimize and (3) develop solutions. These are considered necessary to create an understanding of science (pp. 104-105). On the contrary, the implementation of design-based engineering practices by many science educators is often in classroom actions that focus on erroneous engineering activities (Bybee, 2013). The rationale for including science and engineering practices in the *NGSS* is to further develop students’ ability to apply science (NGSS Lead States, 2013, p. 41). When science educators utilize engineering in the literal sense, they tend to underutilize the potential that engineering design has on building students’ ability to apply science in a more meaningful way (NGSS Lead States, 2013b, p. 19). To support the movement from teaching of scientific inquiry to that of teaching science and engineering practices, as identified in the *NGSS,* it will be necessary for science educators to change the manner in which they use and perceive design-based engineering practices. This will necessitate teachers having the ability to implement design-based engineering practices for teaching science and engineering content. If the proper means for preparing science educators to implement science and engineering practices, as noted in the *NGSS,* are not identified, the new standards will fall short on teaching students ways in which to apply science.

Research on science teaching suggests a tendency in science education to focus on a single set of procedures that overemphasize experimental investigation (NGSS Lead States, 2013b, p. 19). However, design-based engineering practices focus on teaching students the “solving of” ill-structured problems that often have multiple solutions. These methods for teaching students require educators to relinquish some control to the students while still guiding them in their search for answers. Science education largely focuses on conducting experiments, whereas engineering design is the building of apparatuses to test whether or not a solution will work. Recently the NRC suggested K-12 science teachers’ lack of confidence and self-efficacy in teaching these practices (NRC 2014, p. 7). The NRC also reported that, “…at the present time, very few teacher education programs around the country are making efforts to prepare prospective teachers with appropriate content knowledge in more than one STEM subject” (NRC, 2014, p. 7). Other studies have found that when K-12 teachers are engaged in professional development, they focus more on the tools, techniques, processes and technical details rather than on the pedagogical practices of the engineering activity (Custer & Daugherty, 2009). Without sufficient training in teaching design-based engineering practices teachers will continue to underutilize engineering design in the teaching of science.

Some evidence suggests that science teachers perceive their current training as inadequate and feel ill-prepared to wholly integrate engineering activities (NRC, 2014, p. 7). This raises doubt that teachers will successfully adopt and implement design-based engineering practices in the classroom. It was reported the only 4 percent of elementary teachers and only 6 and 7 percent of middle and high school science teachers said they were prepared to teach engineering (Horizon Research, 2013). This use of engineering greatly differs from using the practices of engineering were the focus is to define problems and design multiple solutions. For this reason science teachers may tend to use engineering activities to motivate students rather than a process focused approach. The *NGSS* requires the inclusion of engineering practices and engineering design be taught in science classrooms. As such, it will be critically necessary to examine how these practices will be acquired, perceived, and ultimately implemented by science educators.

Need of the Study

The newly released *NGSS* necessitates that science educators utilize engineering practices in teaching K-12 science content. Documents such as the *NGSS* (NGSS Lead States, 2013), *Standards for K-12 Engineering Education?* (NAE, 2010) and *Standards for Technological Literacy: Content for the Study of Technology (STL)* (ITEA/ITEEA, 2000/2002/2007) emphasizes the implementation of design-based learning practices when teaching engineering practices. Since the practice of defining problems and designing solutions for engineering, as seen in practices 1 and 6 of the *NGSS,* are new to science educators, a methodological framework is needed to guide the preparation of K-12 science teachers in implementing design-based engineering practices to intentionally teach targeted science content.

Problem Statement

To date, science education has focused primarily on defining the content of science education at the expense of its application (NRC, 2013, p.2) and the professional development of science educators continues to prepare teachers in the utilization of scientific inquiry. However, an additional professional development problem currently facing science education is that teacher preparation is not addressing the new engineering practices requirement set forth by the *NGSS*. In particular, there currently is no methodological framework for preparing K-12 science education teachers to use design-based engineering practices to intentionally teach science content and practices.

Purpose Statement

In the context of the stated problem this study will address the need to identify the essential characteristics of a methodological framework that can serve to prepare science educators on the implementation of design-based engineering practices that *intentionally* teach targeted science content. Specifically, the purpose of this study is to characterize a methodological framework for preparing science educators to implement design-based engineering practices to *intentionally* teach targeted science content.

Research Questions

The following research questions will be used to guide this study:

RQ1: How should teacher educators prepare K-12 pre-service science teachers to *define engineering* problems as one of eight *NGSS* practices all students should acquire through science education?

RQ2: How should teacher educators prepare K-12 pre-service science teachers to *design engineering solutions* as one of eight *NGSS* practices all students should acquire through science education?

RQ3: How should teacher educators prepare K-12 pre-service science teachers to intentionally teach targeted science content using their newly acquired abilities to define engineering problems and design engineering solutions?

Definition of Terms

Design-Based Learning (DBL)

A type of project-based learning that involves students engaged in the process of developing, building, and evaluating a product they have designed (Silk, Schunn, & Strand Cary, 2009; Barron et al., 1998).

Design-Based Engineering Learning (DBEL)

A teaching pedagogy such that students create an understanding of engineering by asking a question, to defining a problem, and designing and testing a solution to that problem (Dyn, Agogino, Eris, Frey, & Leifer, 2005; NGSS Lead States, 2013).

Design-Based Science Learning (DBSL)

A teaching pedagogy such that students acquire a scientific understanding of a phenomenon by engaging in ill-structured real world problems that learners attempt to solve using scientific knowledge acquired in a traditional, well-defined science manner (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004).

Engineering

Any engagement in a systematic practice of design to achieve solutions to particular human problems (NRC 2012, p. 11).

Learning Strategies

Teaching approaches used during instruction to help students become familiar and learn new material, which may include lecturing, using case studies, class or group discussion, active learning, and cooperative learning (Kemp & Scwhaller, 1988; Huber & Hutchings, 2005).

Methodological Framework

A structure of the principles, procedures or strategies implemented by a teacher to present and readjust knowledge and experiences in order to enhance the conduct, knowledge, practice, and criteria of individuals. This may include different ways of questioning, explaining, demonstrating, and organizing student collaborations (Lui & Shi, 2007; Shulman, 2002; Suzzallo, 1912; Westwood, 2008).

Instructional Strategies

All the elements necessary in the teaching/learning process. These include curriculum development, laboratory planning and evaluation as well as the delivery system used in the teaching process (Kemp & Schwaller, 1988).

Science and Engineering Practices

Creating an understanding of how scientific and engineering knowledge develops by, using design-based learning to instruct students on how to investigate, model, and explain the world (NRC *Framework* 2012, pp. 42-43).

CHAPTER II: REVIEW of LITERATURE

In preparation for the current study, the author reviewed relevant literature pertaining to the issues of this research. In light of the review, several key areas emerged including engineering practices in science education, designed-based learning practices, and research methods in teacher educational frameworks. These areas provide the foundation for the subsections of this chapter. The conclusion of this literature review presents and supports the rationale for selecting the modified Delphi method for the design of this study.

This review begins with an analysis of science education and the advances it has made in teaching practices. Historically, science educators have received preparation in the practice of scientific inquiry, but have not been well prepared for implementing design-based engineering practices. The National Research Council (NRC) believes that current science education focuses too much on creating a breadth of science knowledge and neglects to provide students with a real life experience. This narrow focus of science education leads to students' lacking the capacity to use science as a means of discovering new phenomena. This realization has motivated a shift towards modifying the practice of science teaching and learning to include engineering design. The hope of the NRC is that this shift will help students to develop the ability to define problem and design solutions for science-based problems.

The review continues with a look into the recently released science standards, the *Next Generation Science Standards* (NGSS). Throughout the *NGSS,* the NRC provides a rationale for why the teaching and learning of engineering practices is essential to the learning of science. Student performance expectations emphasized in the *NGSS* reference the engineering practices students ought to be proficient in when they complete high school. This review then explores current methods for teaching engineering practices. Traditionally, engineering activities are designed to use a form of design-based learning. In comparing these current practices and what the *NGSS* reveals, science education stakeholders' perceptions of an engineering activity are misaligned with how research defines a design activity. The NRC focuses on the integration of the engineering /technological design loop in the *NGSS;* however, there is lack of evidence to support engineering design in the student performance standards. Although many of the *NGSS* standards focus on building a product, they neglect to focus on other important elements such as working in groups, communicating results, obtaining feedback, and engaging in redesign.

Science teacher preparation currently lacks a methodological framework for defining the teaching of engineering practices used to prepare K-12 STEM science educators to use design-based learning to teach science. This study seeks to provide educational stakeholders with the groundwork for a methodological framework aimed at preparing science educators to implement design-based engineering practices in the teaching of science. To this end, this review examines relevant studies that yield data in supporting frameworks. This review supports the Delphi method as the most effective methodological approach for addressing the aforementioned research questions.

Theoretical Framework

The history of science education. John Dewey (1910) believed that science was more than a just a body of knowledge and must include the process of *doing* science in its teachings. From its inception, science education has been criticized for teaching fact-based knowledge rather that preparing students in inquiry and problem solving. Prior to the launch of Sputnik, science education focused on teaching the end results and not the process used to obtain those results (Bybee, 2013; Schwab, 1962). Following the launch of Sputnik, America feared it would no longer be recognized as the world leader in science and technology, and consequently the nation placed heavy emphasis on reforming science, technology, and mathematics education (NCEE, 1983). In regards to science, educating individuals in the methods and facts of science no longer prepared the public to face the challenges ahead. According to Joseph Schwab (1962), science was "…taught as a nearly unmitigated rhetoric of conclusions in which the current and temporary constructions of scientific knowledge are conveyed as empirical, literal and irrevocable truths" (p.62). During this time support grew for moving from solely memorizing science facts to learning about the implementation of scientific inquiry. Science teaching advanced with this notion throughout the 60s and 70's. Science activities involved the use of laboratories and science teaching focused on the use of scientific inquiry to create an understanding of how science happens (Bebee, 2013).

However, the success of this reform dwindled in the 1980's; and once again science education required reform. The 1983 report, *A Nation at Risk: The Imperative for Educational Reform*, declared that "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people" (U.S. Department of Education, 1983, p.5). It claimed that America was losing its scientific and technologically edge compared to the rest of the world (U.S. Department of Education, 1983, p.5). This publication placed the priority on reforming education once more. In response to the findings of *A Nation at Risk*, the American Association for the Advancement of Science (AAAS) initiated a project entitled Project 2061. Named after the year of the return of Haley's Comet, it was a long-range, multi-phased effort aimed at reforming K-12 science education (AAAS, 1989). It brought together panels of experts to identify curriculums for science. The focus of this project was to shift from prior science curricular concerns to the teaching elements necessary to promote science literacy (AAAS, 1989). During the initial investigation the panel found students were no longer meeting the post-Sputnik standards. The researchers concluded that there was a critical need for reforms in science, technology and mathematics education.

The purpose of science education. *Science for All Americans* (*SfAA)* (AAAS, 1989), the first publication resulting from the initial research of Project 2061, documents the nature of science, mathematics, and technology and emphasizes the connections and similarities between the disciplines. Science needs evidence to support its theories; this progress can only be accomplished through the use of technology and mathematics (AAAS, 1989). *SfAA* focused on how each of the disciplines supplies each other with further development within their own disciplines and why each discipline complements each other. Following this vision of connections between the disciplines, AAAS published the *Benchmarks for Science Literacy* (AAAS, 1993). The purpose of this publication was to establish guidelines for science, technology and mathematics literacy. The goal of this document was to define a scientifically literate K-12 student (AAAS, 1993).

> The common core of learning in science, mathematics, and technology should center on science literacy, not on an understanding of each of the separate disciplines. Moreover, the core studies should include connections among science, mathematics, and technology and between those areas and the arts and humanities and the vocational subjects. (AAAS, 1993, p. xii)

SfAA necessitated the connections that must be made between science, mathematics, and technology in order to enhance student learning in the area of science. Following *SfAA* the *Benchmarks* set out to determine what the substance and character of such an education might look like. Both of these documents focused on the content of what science curriculum should entail. The *Benchmarks* made a conscious effort to make connections between the disciplines of

Science, Technology and Mathematics and gave guidance in the formation of curriculum to meet these goals.

Following the work of Project 2061 the *National Science Education Standards* (*NSES)* (NRC, 1996) were published. This work provided guidance to science education stakeholders by providing instrumental support in curriculum development. *NSES* was unique because it provided examples throughout the standards of practice and explicated what science should look like in the classroom (NRC 1996, p. 16). Furthermore, it defined what teachers should know and be able to do in science. The *NSES* poses five criteria used to define an effective science teacher.

- The vision of science education described by the *Standards* requires changes throughout the entire system.
- What students learn is greatly influenced by how they are taught.
- The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned.
- Student understanding is actively constructed through individual and social processes.
- Actions of teachers are deeply influenced by their understanding of and relationships with students. (NRC 1996, p. 28)

It was in this document that science teaching refocused on the teaching pedagogy of scientific inquiry. It focused science teaching on asking the question “how” rather than “why”. After the release of the *NSES,* it was not until 2000 when the Committee on Development of an Addendum to the National Science Education Standards on Scientific Inquiry published *Inquiry and the National Science Education Standards* (NRC, 2000). It provided educators with five elements that focused on inquiry lesson design. However, due to the constraints of the classroom, as well as a lack of resources and teacher training, scientific inquiry has yet to be implemented as intended (Bybee, 2013).

The science education community realizes that the time has come to once again consider reformation of the K-12 science classroom (NRC 2012, p. ix). The *Benchmarks* and the *NSES* were the basis for the *NGSS*. The innovation of the *NGSS* shifts the teaching pedagogy of scientific inquiry to that of practices. The *NGSS* states that inquiry is only a part of the scientific process and that by expanding the teaching of practices the learning of science will be enriched (NRC, 2013). Today the science community is focused on the application of science along with developing science knowledge. The teaching and learning of science has shifted from teaching only scientific inquiry to also include engineering design practices.

Together, science, technology and engineering have been perceived as the great integrator of the core disciplines of reading, writing, and mathematics. To engage students fully in the practices of scientific inquiry and engineering design, students need the skills developed by engaging in these disciplines to gather data and communicate results. In science the ability to examine and critique primary source documents provide students with insight into what has been done before and provides them with the background knowledge with which they can build further inquiry. Furthermore, students also must be able to communicate the results of their findings in a way others can understand.

According to the NRC (2012), science education in the United States fails to provide students with a strong background in STEM. The NRC believes this is because science is not systematically structured throughout the K-12 grade levels, focuses too much on creating a breath of science, and neglects to provide students with a real life experience (NRC 2012, pp. 25-27). To address these issues, the idea of the NRC is to educate and engage K-12 students with the foundational knowledge of science and engineering towards encouraging students to think of these areas as potential future careers (NRC 2012, p. 10). These concerns, listed above, lead to the mission of the NRC "to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines" (NRC 2013, Appendix I p. 1). To accomplish this "The *Framework* recommends that students explicitly learn how to engage in engineering design practices to solve problems" (NRC 2013, Appendix I, p. 2).

Based on research reports such as *Taking Science to School* (NRC, 2007) the NRC structured the *Framework* around the following guiding principles:

1. Children are born investigators
2. Focusing on core ideas and practices
3. Understanding develops over time
4. Science and engineering require both knowledge and practices
5. Connecting to students' interests and experiences
6. Promoting equity. (NRC 2012, pp. 24-29)

The NRC concluded that children are born investigators and students are capable of learning more sophisticated concepts than original thought. Prior to this conclusion, students learning in K-5 focused only on descriptions of scientific data (NRC, 2012, p. 25). The *Framework* moves away from this notion and is designed to engage students in scientific and engineering practices from the beginning. The NRC also focuses the framework on a core set of ideas. Prior to the *Framework* the NRC believed the content of sciences covered too many disconnected topics (NRC, 2012, p. 25). The NRC believes that providing a deeper exploration of key concepts will foster a deeper understanding of science practices (NRC, 2012, p. 25). The NRC designed the

Framework to promote learning over time and to allow educators to connect to prior learning experiences. The idea is to support and build upon the concepts learned prior so students can sustain what they have leaned (NRC, 2012, p. 26). The NRC believes that knowledge and practice go hand in hand. By incorporating the uses of practices into science education students not only gain the knowledge of science; they learn how to apply it (NRC, 2012, pp. 26-27). Connecting to students' interest is also an assumption of the NRC. The *Framework* is designed to sustain attraction to science by connecting learning to what is relevant in students' lives outside the classroom (NRC, 2012, p. 28). Lastly, the NRC believes all students should be allowed equal access to all science has to offer. These guiding principles provide the foundational structure along with the content used to construct the *Framework* and the *NGSS*. It also provides structure to the three dimensions of the *Framework* which define the knowledge and practices students should acquire by the end of high school. This progression of events has led to the current direction of science education and a need to understand how engineering practices will be used in the teaching of science. These findings provide a theoretical framework for this study and provide direction for how this study is constructed.

Progression in the Next Generation Science Standards

There are many factors unique to the *NGSS* that differ from prior standards documents. The sequencing of student learning between grade levels, the shift from focusing only on scientific inquiry to the application of science and engineering practices, and a greater focus on the importance of integration between the STEM disciplines have led to a new approach for how teaching and learning should take place in science education. Based on research presented in *Taking Science to School* (NRC, 2007) the NRC realized it needed to promote better progression of science learning across grade levels. The *NGSS* emphasizes the importance of making connections across grade levels and developing standards that build on student's prior knowledge. The *NGSS* focuses on the education of a student rather than teaching them more science content. A major goal for the *NGSS* is to help students to develop an understanding of the connections between science and other disciplines.

The *NGSS* standards focus on the symbiotic connections between science and engineering rather the administration of more science content. The NRC believes science has far too long focused on a breadth of science knowledge rather than depth and strives to rectify this in the *NGSS* (NRC, 2012, p. 25). Each of the standards begins with a student performance expectation (PE). The PE outlines what students ought to demonstrate at the end of instruction. The PE states that a scientifically literate person will understand and be able to apply the core ideas of science in each of the science discipline and gain experience in the practices of science and engineering and in the crosscutting concepts. (NGSS Lead States, 2013, p. XXIII). PE statements are also used to identify what will be assessed in that science standard. The PE is not designed to be an instructional strategy or lesson objectives, rather it is a guide for science stakeholders to build from. The goal of the standards is simply to state what students should be able to do at the end of instruction.

To support the PE, researchers of the *Framework* recommended K-12 science education is to be built around three major dimensions: science and engineering practices, crosscutting concepts and disciplinary core ideas (NCR, 2012, p. 2). Each of these domains is intended to be integrated into the PE. The domains are listed within the PE and describe the elements used in the formation of the corresponding PE. These three dimensions can be found in the foundational boxes in each of the standards. Another feature of the standards is the connection pages. Each PE references a connections page, which is designed to support and make connections between other corresponding PEs.

The science and engineering practices domain provides information on the practices used to construct the PE. It also informs the reader the design methods scientists and engineers employ so it may be utilized in the planning related to the PE. The science and engineering practices used consist of the eight categories found in the *Framework* (NGSS Lead States, 2013b, p. 48). These eight practices are briefly discussed in the introduction of this document and will be explored further later in the document. The second element related to each PE is the disciplinary core idea (DCI). The DCI builds upon what students should already know about science and states what students should know and be able to do after completing the PE. The last dimension, crosscutting concepts, identifies core concepts of the lesson that are applicable throughout all of science. Each or the PEs also identifies its connection to the Common Core State Standards (CCSS).

Another key feature in the PE is the identification of what students should have experienced prior. This origination of the PE allows teachers to combat the problem of sequential organizing described in the *Framework*. The difference between the *NGSS* and previous standards is a shift away from teacher driven lessons and activities to student-led learning. In addition, the focus of the *NGSS* deemphasizes memorization of facts and emphasizes the development of knowledge and practical skills for applying science in the real world. The *NGSS* provides students with new tools that inspire and develop curiosity of science and engineering.

Purpose of engineering practices in science education. In the review of *NGSS* and *Framework* the term engineering is viewed by the NRC as a practice. The NRC states; “We use the term engineering in a very board sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems" (NRC, 2012, p. 11). The purpose for introducing engineering practices in *NGSS* is to add a new dimension to the teaching and learning of science content. The NRC states, "From a teaching and learning point of view, it's the iterative cycle of design that offers the greatest potential for applying science knowledge in the classroom and engaging in engineering design" (NRC, 2012, pp. 201-202). The NRC suggests that the methods of scientific inquiry closely mirror that of engineering design (NRC, 2012, p. 12). The NRC reasons that when these two disciplines are taught in unison, students will gain a greater appreciation for science and engineering and the ability to apply this knowledge in the solving of problems (NRC, 2012, pp. 9-11).

The implantation of engineering practices in science education, according to the NRC, will take shape in the form of teaching students engineering design (NRC, 2012, p. 46). Engineering design has been intergraded into the student performance expectations of the standards. The overarching goal of this is to provide science educators with a method of delivery to intentionally deliver science content through the use of engineering practices. However, without proper teacher preparation in the uses of engineering practices in the teaching of science content it is difficult to determine the effectiveness this will have on student learning.

Implementation of engineering practices in science education. In a report entitled "*Standards for K-12 Engineering Education?*" The National Academy of Engineering (NAE) said that, "although theoretically possible to develop standards for K-12 engineering education, it would be extremely difficult to ensure their usefulness and effective implementation" at this time, in part because "there is not at present a critical mass of teachers qualified to deliver engineering instruction" (NAE, 2010, p. 1). Simplify put, a greater number of teachers with training in the areas of science and engineering practices are needed to implement the practice outlines presented in the *NGSS*.

Traditionally, science educators have been instructed in the use of scientific inquiry to conduct and design classroom lessons in science (NRC, 2012, p. 30). Without proper teacher development of engineering design it is hard to envision students grasping the concept of engineering design and the solving of ill structured problems. Teacher's knowledge of engineering is limited in the ways engineering operates in the real world. A recent NAS report, which focuses on integrated STEM Education, suggested that K-12 teacher preparation in science and mathematics is limited and that teachers lack confidence and self-efficacy in their ability to teach (NRC, 2014, p. 7). Thus, it is unlikely that science teachers have a sufficient grasp of engineering content to include in an integrated approach.

Although the method of scientific inquiry and engineering design mirror each other in their method of approaching and solving problems, science and engineering differ in the ways they are taught (NRC, 2012, p. 26). It was revealed that science teachers' teaching style depends on the pedagogical practice of scientific inquiry. The NRC (2012) believes there has been a tendency in science education to focus on a single set of procedures that overemphasizes experimental investigation (p. 43). This has led to students who have knowledge of scientific concepts, but lack the ability to apply science practices in real world applications. The key to effectively integrating engineering is to have teachers in the classroom who have a deep understanding and appreciation for engineering (Reid & Baumgartner, 2011). This method of teaching focuses on examining well-structured problems and then expanding them through experimentation and application of the scientific method. Modeling and experimentation is used to support new scientific theories form new hypotheses. In turn this creates more opportunities for science to explore. However, engineering design focuses on the solving of ill structured problems that often have multiple solutions. These methods for teaching students require educators to relinquish some control to the students while still guiding them towards finding solutions. Science education focused on conducting experiments, whereas engineering design is the building of apparatuses to test the efficacy of a solution. Beyond the logistics of constructing devices, which may require a long period of time to complete, science teachers have little experience and resources to conduct these types of activities. Preparing science teachers in engineering design will require them to learn effective pedagogical approaches to problem solving in relation to engineering design.

Another obstacle is how science teachers will acquire these skills in engineering. In 2009, a study conducted by Rodney L. Custer and Jenny L. Daugherty, which focused on teacher professional development at the secondary school level, highlighted how ill prepared teachers are for teaching engineering. Custer and Daugherty (2009) reported that science, technology and mathematics teachers are traditionally not prepared to teach the concepts of engineering. The focus of K-12 teacher preparation and development is concentrated in the disciplines of science, math or technological literacy and typically not in engineering. The NAS reported that “At the present time, very few teacher education programs around the country are making efforts to prepare prospective teachers with appropriate content knowledge in more than one STEM subject”(NRC, 2014, p. 7). Furthermore, resources for teacher in-services are limited and ill structured. It was found that when K-12 teachers were engaged in professional development, they focused more on the tools, techniques, processes and technical details than on the pedagogical practices of the engineering activity (Custer & Daugherty, 2009).

The approach to educating students in the application of science, as outlined in the *NGSS*, will require science educators to have an understanding of how to use engineering practices to enhance the learning of science. The implementation of engineering practices for the purpose of teaching science content will present educators with many challenges when implement the use of engineering practices in the teaching or science content. This is why it is critical to investigate the characteristics of a mythological framework of how this will occur in the preparation of teachers. Without a means of preparing science teachers this reform will never be implemented as intended.

Perception of engineering practices in science education. The NRC stated that many teachers were pleased with the integration of engineering and technology in the standards; however there were also concerns (NRC, 2012, p. 337). Teachers were apprehensive to the amount of space dedicated to engineering and technology, the core ideas recognized by the *Framework*, and the ability to teach these concepts in K-12 (NRC, 2012, p.337). Science teachers recognize the implementation of engineering practices is a conceptual shift from the way they currently teach science. Educators believe to effectively carryout the standards in practice, as they were designed, it will take more classroom time and a deeper understanding of engineering concepts and an understanding of engineering design pedagogical practices.

The American Society for Engineering Education reported that teachers view engineering as a difficult to very difficult profession (Douglas, et al., 2004). In 2004 the ASEE hosted a leadership workshop on K-12 engineering outreach. During the workshop, educators were asked about their perceptions of what worked for educating students in engineering. Findings revealed that many of the undertakings believed to work for student's involved hands-on activities perceived by students as fun (Douglas, et al., 2004). It was also noted that adding engineering content in the form of writing or history added an interdisciplinary approach to science and mathematics classes (Douglas, et al., 2004). These findings reflect a preconceived notion among science teachers that engineering must be fun and hands-on learning activities are necessary for students to understand engineering as it relates to science.

***NGSS* performance expectations.** The conceptual framework of the *NGSS* emphasizes that the practice of teaching engineering design is critical in the understanding of science (NRC, 2012). Without engineering design as a mode of delivery, scientific inquiry by itself produces students that process scientific knowledge, but lack the skills to practice science as intended (Bybee, 2013; NRC, 2012). Research shows that students learn by making connections to prior knowledge and building upon that knowledge (NRC, 2007). With these factors in mind the *NGSS* integrates engineering practices in the form of engineering design into each of the PEs found in the standards. Beyond just engineering practices, the *NGSS* provides educators with means to connect student's prior experiences to the new core idea they are learning about. The PE also describes what students should be assessed on to measure their depth of understanding of engineering practice. Engineering practices are also included in the PEs of each grade level.

It is evident that engineering design is not an afterthought in the *NGSS* as it is integrated throughout the standards document. The standards provide teachers with direction on how engineering design is applied within the PE. Interestingly, there are no clarification and assessment boundary statements for the engineering design PE for each grade level. This is a key component of the other PEs and guides the user on what students already know and what they ought to be able to do. Without these statements it is difficult to build from prior knowledge and assess students' understanding of the engineering design PE.

It is revolutionary that engineering design is held in such high regards in the *NGSS*. However, including engineering design in the standards does not necessarily mean teaching and learning of engineering practices will be implemented in the K-12 classroom. In order for engineering design to have an effect on student learning, teachers will have to be instructed on how to purposely integrate engineering design in to the performance expectations of students (Pratt, 2013, p. 22).

***NGSS* eight science and engineering practices**. The intent of *NGSS* is to overcome the narrowness of science education that science is more than an isolated body of facts (NRC, 2012, p. 41). It is evident in the *Framework* that science has the tendency to focus only on the knowledge of science and not how it is applied. The NRC presents that current science education is focusing too heavily on scientific inquiry and so limits the creative process (NRC, 2012, p. 46). Teachers tend to focus on the content of science and have difficulty engaging students in the practice of science. To address this problem, the *NGSS* focus shifts from engaging students in the pedagogical method of scientific inquiry to the use of scientific and engineering practices in the teaching of students. The *Framework* uses the term "practices," instead of a term such as 'skills,' in order to stress that engaging in scientific inquiry requires coordination both of knowledge and skill simultaneously' (NRC, 2012, p. 30). Engaging students in the practices of science and engineering allows students to view science and engineering as a process rather than a single method of procedure (NRC, 2012, p.43). Moving from just teaching scientific inquiry provides students with a deeper understanding of science and engineering.

The *Framework* identifies eight practices that are essential for all K-12 students to learn. These practices are highlighted in the first dimension (scientific and engineering practices) and focus on how the procurement of scientific knowledge requires the development of both science knowledge and skills (NRC, 2012, p.41). The objective of each of these practices intends to promote, extend, and/or enhance student learning by developing students' ability to use these skills in supporting and demonstrating their understanding of science and engineering (NRC, 2012, p. 49). The integration of science and engineering practices provide science educators with guidance on how they can do more. It allows for students to be engaged in the process of science and develops students' ability to obtain problem solving skills.

Student engagement in engineering practices. The NRC believes that the integration of engineering into the teaching of science is fundamental in the development of student learning in science. In each of the eight practices educators are encouraged to engage and teach students the skills necessary to develop an understanding of the standard. Research has shown that engaging students in engineering practices and engineering design requires students to apply science and mathematics in practical applications. By practicing engineering in K-12, students experience how the disciplines of Science Technology Engineering and Mathematics (STEM) work together and that they are not isolated subjects. It also provides students with the ability to develop multiple solutions to the same problem and create critical thinking skills. Furthermore, beyond creating excitement in the classroom it generates interest in the STEM field as a possible career choice.

Engagement in science and engineering practices engages students in a practical approach towards learning how science operates in the real world. The practices of science focus on asking the questions vs. the practices of engineering which designs or provides a practical application of a solution (NRC, 2012, pp. 45-47). Each of the eight practices outlined in the *Framework* provides educators guidance on how these practices are integrative in nature. The practices are not individual skills student learn but rather elements of a set of procedures used to solve problems. The *Framework* also highlights that these practices do not occur in any specific order and that they can be interchanged to enhance student learning.

The first practice of asking questions (for science) and defining problems (for engineering) focuses on how scientists ask questions and how students ought to formulate questions (NRC, 2012, p. 56). From the engineering lens the standards describe how students should possess the ability to define the problem and identify constants of the problem towards designing an approach that solves the problem (NRC, 2012, p. 56). Science begins with asking a question; engineering begins with defining a problem. Engaging in this practice, students gain the ability to ask good questions and define problems.

In the second practice, developing and using models, students explore how models are used to explain scientific findings. Engineering models are used to identify problems or test possible solutions to a problem. Learning these practices engages students in the ability to describe, predict, and test theories and solutions to problems (NRC, 2012, p.58). Practice three focuses on building students' ability to test scientific theories or describe how something works, from the engineering standpoint investigations are used to explore technological solutions to a problem (NRC, 2012, p. 61). Analyzing and interpreting data is the fourth practice and seeks to develop the ability to present data in a meaningful way (NRC, 2012, pp. 61-62). Beyond just developing the skills of analyzing data, the description also requires students to develop the capability to report their findings in a mathematically sound way. This is expanded on in practice five, using mathematics and computational thinking, where the objective of this practice is to engage students in the use of mathematics so that students can identify relationships and develop the ability to make predictions (NRC, 2012, p. 65). Practice six emphasizes students' ability to develop explanations (for science) and design solutions (for engineering). *Practices one and six* are the only practices that focus on the difference between science and engineering practices. Constructing explanations is a skill scientist use to describe why something happens in nature. In engineering, developing a solution to a problem is in the form of a technological device. The seventh practices intent is to engage students in formulating arguments from evidence. The rationale for this practice follows that students need to possess the skills necessary to support their finding based on the evidence they have discovered (NRC, 2012, p. 73). The last of the eight practices seeks to develop the ability of students to become critical consumers of information (NRC, 2012, p. 76). Listed above are brief descriptions of what the intent of each of the eight practices entail. Prior to the issue of the *NGSS*, the practices described above have not been an integral part of the teaching and learning of science. It is the goal of the new standards to provide students with the ability to utilize these skills in the application of science and engineering practices. The NRC believes doing so will enhance students' ability to apply science to develop the knowledge and use of scientific and engineering practices in practical applications.

Structure of performance expectations in the *NGSS*. The NRC identified three essential building blocks which form the three dimensions of the *NGSS:* (1) Science and Engineering Practices (2) Disciplinary Core Ideas, and (3) Crosscutting Concepts (NRC, 2012, p. 29; NGSS Lead States, 2013, Introduction. p. xv). The building blocks define the student learning that students must acquire to develop a deeper understanding of the practices of science. The PE is the fundamental component of the *NGSS*. PEs explain what students must do to demonstrate that they have the necessary skills, core ideas, and conceptual knowledge. These components are incorporated into each of the disciplinary core ideas of the standards and provide structure for educators designing curriculums. The purpose of PEs is to outline the teaching strategies used by teachers and curriculum developers. The foundation box identifies the learning outcomes for students.

Scientific and engineering practices: Dimension #1. PEs are found in dimension #1 of the *NGSS*. The NRC has made a point to integrate the practices of engineering into the teaching and learning of science education. Dimension #1 of the *NGSS* focuses on this concept. The focus of dimension #1 is on important practices, such as modeling, developing explanations, and engaging in critiques and evaluation (NRC, 2012, p. 44). Dimension #1 of the *NGSS* describes (a) the major practices that scientist employ as they investigate and build models and theories about the real world and (b) a key set of engineering practices that engineers use as they design and build systems (NRC, 2012, p, 30). Within the *Framework* (2012) a strong case for integrating the practices of science and engineering exists;

> "Moreover, the line between applied science and engineering is fuzzy. It is impossible to do engineering today without applying science in the process, and, in many areas of science, designing and building new experiments requires scientists to engage in some engineering practices. This in interplay of science and engineering makes it appropriate to place engineering and technology as part of the science framework at the K-12 level." (NRC, 2012, p. 32)

However, it is difficult to determine in the *NGSS* if these practices are to be taught, learned, and assessed in the standards. The following is evidence supporting this claim.

The NRC identifies how the science and engineering practices are integrated into both inquiry and design by dividing them into three spheres of activity (Figure 1).

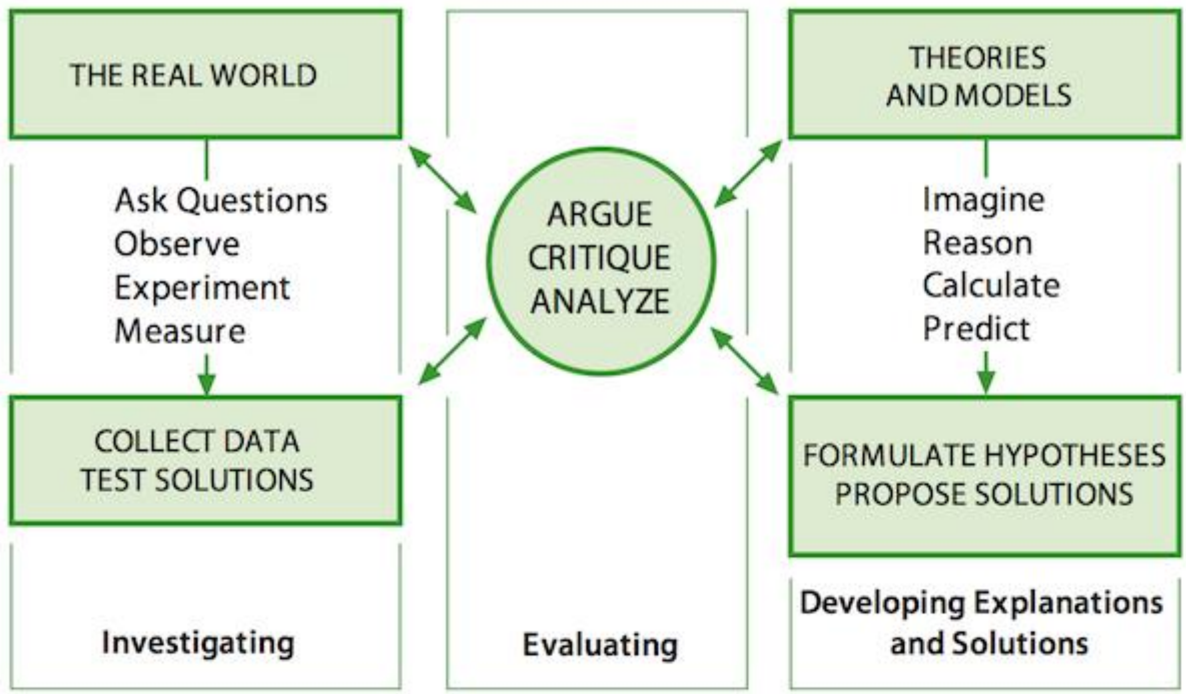


Figure 1. **The Three Spheres of Activity for Scientists and engineers**. Adapted from "**A Framework for K-12 Science Education" by** National Research Council (NRC). 2012. p. 45. Copyright 2012 by the National Academy of Science.

The first sphere of the model provides explanation on how investigation is conducted in science and engineering. In the *Framework* it states: "scientists determine what needs to measured; observe phenomena; plan experiments; programs of observation, and methods of data collection; build instruments; engage in disciplined field work; and identify sources of uncertainty. In comparison, engineers engage in testing that provides data for informing designs (NRC, 2012, p. 4bc5). The other side of the model is devoted to developing explanations and solutions. Scientists operate in this area by developing models or hypotheses that lead to the development of new questions for science (NRC, 2012, p. 45). The engineering section of this sphere highlights the production and building of designs (NRC, 2012, p. 45). Evaluating is the sphere that combines the other two spheres. Practices that take place in this area are activities that focus on argumentation and critique (NRC, 2012, p. 46). The NRC has created a need and rationale to integrate engineering practices as highlighted in this figure, but it is still unclear how these practices will be developed in the context of science curriculum.

Asking questions (for science) and defining problems (for engineering): Practice 1. According to the NRC, science and engineering are similar in many of their practices. Where they differ is in the practice of asking questions for science and defining problems for engineering. The *NGSS* identifies this as Practice 1. Science is the study of the universe; it is the study of how things work. Engineering is solving problems to satisfy human needs, where there are multiple solutions to a problem. Science is based on the theory of inquiry. Engineering is grounded in the theory of design. Engineering asks questions that are designed to define problems. Engineering further asks questions that underline the need of the problem. So the goal of Practice 1 is to explain phenomena by using scientific inquiry, then turning towards engineering to define and solve the problem using engineering design.

When examining Practice 1 it is challenging to find where the teaching and learning of engineering practices will occur. Within the *NGSS* each performance expectation outlines the science and engineering practice it will address. In kindergarten through second grade, PEs focuses on developing students' abilities to obtain information, make observations, gather information, and design a new or improved objects or tool. Obtaining information, making observations and gathering information are practices associated with the scientific method. Design of a new or improved object or tool requires the use of engineering design to define the problem.

When examining the third, fourth, and fifth grade performance expectations in relation to Practice 1 with the exception of Motion and Stability, the practice of defining problems is not addressed in any other PEs. The only other place pertaining to problem definition is addressed in the PE of engineering. In middle school the practice of defining solutions is in the PE of engineering; the other two times Practice 1 is referenced it focuses on the science aspect of asking questions. In the high school the only evidence of defining solutions are found in the PE of engineering. The goal is to develop the skill of identifying constraints for solutions.

It is difficult to find evidence to support the practice of defining solutions in the performance expectations of students. The majority of the PEs that focus on developing students' ability of Practice 1 focus on asking questions rather than defining problems. Practice 1 is referenced 13 times throughout the standards; two times in kindergarten, two times in third grade, one time in fourth, two times in the three through five standards, three times in middle school and two times in high school. In comparison to the other eight practices Practice 1 is only present in approximately 21 percent of the PEs, the least referenced of the practices. Of the 21 percent the skill of defining problems is only present in five of the PEs. This minimal use of defining engineering problems in Practice 1 makes it hard to justify if students will truly understand how engineering solutions are developed.

Constructing explanations (for science) and designing solutions (for engineering): Practice 6. The goal of Practice 6 is to have students construct explanations for science and design solutions for engineering. Practice 6 is found in 44 of the 61 performance expectations. The aim of Practice 6 is develop their ability to construct explanations for phenomena that occurs in science and choosing design solutions for engineering (NRC, 2012, p. 52). What is unclear in the *Framework* and the *NGSS* is the process of engineering design. The *Framework* gives an explanation of the engineering design process but does not provide insight on how the process will be implemented in each of the grades. The integration of the engineering design in most cases is reduced to providing students with an opportunity to choose an optimal engineering design solution to a problem.

In science, theories are used to construct best possible explanations for describing how the world works. According to the *Framework*, a theory in science starts with an idea followed by an experiment to test one or more hypotheses, which may ultimately support a theory (NRC, 2012, p. 67). New evidence is then sought to modify or strengthen the theory. The *Framework* describes a hypothesis as a plausible explanation for the phenomena based on what is observed (NRC, 2012 p. 67). The process of science begins with a theory, which is either supported or rejected through hypothesis testing. In engineering the cycle of design begins with a practical problem that addresses a human want or need. The next step is to design and create a solution to the problem that meets that human want or need. Then the process of evaluation is used to assess if the design is successful in meeting that human want or need. The *NGSS* is designed to help students progress through the grades. The *Framework* suggests that students start with learning how to construct explanations. During the middle school students start more educated guesses and then modifying these guess to lead them to an answer. The theory of design is intergraded throughout the each grade level in the form of designing solutions.

In regards to Practice 6, science education classifies what students should be able to accomplish by 12th grade into two categories. The first pertains to what students should be able to accomplish in science and the second identifies what students should have the opportunity to experience in engineering. The skills students should acquire in science revolve around generating hypotheses, testing hypotheses, and putting evidence together for rejecting or supporting a hypothesis (NRC, 2012, p. 69). To demonstrate proficiency and understanding of engineering design, students are asked to solve design problems using scientific knowledge, undertake design projects by engaging in all steps of the design cycle, construct device or implement a solution and evaluate and critique design solutions (NRC, 2012, p. 69). To classify what students should be able to do in both science and engineering; students participate in one of two methods of teaching. In science students will be engaged in activities in which they generate and test hypotheses. In engineering students are engaged in the engineering design process. In simpler terms, students either participate in observing or building.

When examining the PEs of the *NGSS* K-5 students are engaged in activities that require them to ask questions to obtain information, make observations, determine the cause and effect relationships of objects, and predict outcomes of events. The PE's listed below are examples of how the *NGSS* defines these activities;

- Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object. (NGSS Lead States, 2013, p. 16)
- Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing. (NGSS Lead States, 2013, p. 30)
- Identify evidence from patterns in rock formations and fossils in rock layers for changes in a landscape over time to support an explanation for changes in a landscape over time. (NGSS Lead States, 2013, p. 39)

Listed bellowed are examples in the *NGSS* relating to the teaching of engineering design along with clarification statements highlight what types of activities should be engaged in;

- Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land. *[Clarification Statement: Examples of solutions could include* *different designs of dikes and windbreaks to hold back wind and water, and different designs for using shrubs, grass, and trees to hold back the land.]* (NGSS Lead States, 2013, p. 21)

- Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. * *[Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.]* (NGSS Lead States, 2013, p. 35)
- Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. **[No Clarification Statement]* (NGSS Lead States, 2013, p. 53)

In comparison to the goals of engineering design as outlined in the *NGSS*, the K-5 PE's focus mostly on providing students with examples of devices and solutions rather than engaging them in hands-on engineering design activities. In K-5 science education it is difficult to determine how students will be engaged in all the elements of engineering design based on these standards. Engineering design activities look like the following in middle school;

- Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. * *[Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance.*

Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.] (NGSS Lead States, 2013, p. 56)

- Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. * *[Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]* (NGSS Lead States, 2013, p. 59)
- Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. * *[Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.]* (NGSS Lead States, 2013, p. 61)

These activities have students building devices to conduct experiments in science. Although these activities encourage students to build a device, they are not requiring that students think about and design a solution to a problem that satisfies a human want or need. The devices that result from these activities are predetermined. As found in the K-5 PE's it is also difficult to determine how students will be engaged in the engineering design process.

High school science and engineering PEs largely focus on applying and constructing scientific explanations.

- Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history. (NGSS Lead States, 2013, p. 119)
- Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. (NGSS Lead States, 2013, p. 125)

The only evidence of engineering design is found in the disciplinary core idea of engineering design. The PEs found in the *NGSS* offer no clarification statement and offers no guidance on what students should be assessed on. Furthermore, science educators can meet these requirements never having engaged students in hands-on activities.

- Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (NGSS Lead States, 2013, p. 129)
- Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. (NGSS Lead States, 2013, p. 129)

The *Framework* and the *NGSS* state that "Engaging in the practices of engineers likewise helps students understand the works of engineers" (NRC, 2012, p. 42). The Framework makes a strong case and defines engineering practices very well. However, most of the practices found in the PEs in regards to engineering only focus on part of the engineering design process. Based on the evidence found in the Dimension #1, Practices 1 and 6 of the *NGSS* it is challenging to determining if engineering practices are specifically targeted as learning outcomes of K-12 science students.

Engineering Practices

In the STEM disciplines engineering activities are viewed as the “doing of” something or the application of learning. The major goal of engineering is to solve problems that arise from a specific human need of desire (NRC, 2012, p. 27). These activities usually take the form of some type of project that engages the students in the solving of a real world problem. The NRC defines engineering activities as a series of steps that revolve around the engineering design process. Listed below are the steps identified in the *Framework* as the systematic approach to engineering design.

1. Identify the problem
2. Define specifications and constrains of problem
3. Generation of ideas to solve problem (e.g., brainstorming)
4. Building of models
5. Testing of solutions
6. Evaluate and redesign (NRC, 2012, pp. 46-47).

The series of practices define the engineering design process as indicated in the *Framework* and the *NGSS*. Although, there are some variations in language between this and other engineering design models the key components are fundamentally the same.

Science education traditionally begins with a well-defined problem which then students address via experimentation. Engineering design takes this a step further and asks students to identify their own problem and then to find a solution to it. Sometimes these engineering activities have students participate in identifying the problem, as well as determining what knowledge they will need to acquire on the way to finding a solution. Some activities have students learn content first and then use that knowledge to solve a problem. Certain engineering activities are short and have students present their findings in the form of presentation, whereas others are lengthier and engage students in a larger design project. The next section of this review provides examples of inquiry-based, problem/project, and design learning models. During the search for these practices many variations of inquiry based learning methods were found. Each has a different approach to delivering instruction to students. However, what each had in common was the goal of identifying and solving an ill structured problem, a focus on the use of groups, presentation of completed work, and provision of student feedback to peers. The following section will define the learning models and provide an explanation on how they can be implemented in practice.

Problem-based learning. Problem-based learning is a learner centered approach that requires students to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savery, 2006, p.12). It has been widely accepted as a teaching method in diagnosing patients in the medical field because of its focus on identifying and solving problems with multiple outcomes (Barrows, 1986). Due to the vast quantity of data in the medical field, it was found to be more beneficial for students to learn how to become problem solvers rather than memorizing medical facts (Barrows, 1986). Problem-based learning focuses on the presentation of a real life problem that cannot be solved with a single solution. Students are engaged in defining the problem and generating a list of what is known about the problem. Following this investigation students then design a solution or product that attempts to solve the problem and presents findings. This teaching and learning method is designed to foster free inquiry while students develop knowledge and design a solution to a problem (Barrows, 1996). It is interesting to note this rationale nearly mirrors what is currently happening in the field of science and engineering, where the focus has shifted away from producing students with science knowledge to producing students who can practice in these disciplines.

In the classroom, student learning focuses on an open-ended question that requires students to define a problem in the form of a problem statement. The problem is then examined and research is conducted to form an inventory of what is already known about the problem and what additional knowledge is required. The development of the solution is guided by a teacher who encourages students and asks informative questions. Solutions are then presented and shared with others.

Project-based learning. Project-based learning is a teaching pedagogy in which teachers serve as facilitators in lessons that engage groups of students (usually) in real world problem activities (Barron & Darling-Hammond, 2008; Thomas & Mergendoller, 2000). In comparison, this method is much like problem-based learning such that it is used to solve real world problems. It differs, however, in the creation of a project and the amount of time it takes to implement in the classroom. In the classroom project-based learning revolves around three components: critical thinking, collaboration, and communication.

In the classroom, project-based learning involves addressing a complex problem and carrying out a lengthy task. This is seen as one of the major obstacles in project-based learning, especially given constraints of the learning environment and time limitations in K-12 education. During problem-based learning, students usually follow a prearranged list of steps; however in project-based learning students follow a process with which they work to solve a problem. The solution to the problem in project-based learning also involves the creation of a project or some type of demonstration. In problem-based learning the solution could be the form of a presentation or report. Both project-based and problem-based learning methods seek to give students experience in solving real world problems; however, in project-based learning students tend to focus on real world tasks (Larmer, 2014).

Design-based learning. Design-based learning (DBL) is one type of project-based learning that involves students engaged in the process of developing, building, and evaluating a product they have designed (Silk, Schunn, & Strand Cary, 2009; Barron et al., 1998). The focus of this type of student learning is on the design of a project that leads to the construction of something. DBL is a problem-based learning approach in which content knowledge is introduced as necessary; traditional inquiry-based lessons introduce the content of the lesson before the activity (Silk, 2008).

In the classroom, problems are presented to students where design is the catalyst for learning. The problem is presented to the students as a challenge to be solved. The students then identify the constraints of the problem and set the criteria by which the solution to the problem is overcome. Once constrains are identified, students then research ideas to solve the problem. The learners then build and present their solution to the problem. During the presentation students receive feedback with which they then can use to make modification to their projects. The cycle then begins again.

DBL has been criticized because students and teachers are sometimes more focused on the building of the apparatuses rather than the learning that supports the project (Silk, 2008). This was also found when K-12 teachers were engaged in professional development; they focused more on the tools, techniques, processes and technical details than on the pedagogical practices of the engineering activity (Custer & Daugherty, 2009). This will be a challenge to overcome when teaching engineering design in science.

Design-based science learning. Design-based science learning (DBSL) is a teaching pedagogy were students create scientific understanding by engaging them with ill structured real world problems with which learners attempt to solve using scientific knowledge learned in a traditional well defined science manner (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004). The process engages students in a manner similar to DBL as it focuses on having students identify and define a problem, conduct research on the problem, construct a product and obtain feedback; however where it differs is in the ascertaining of science content. In a DBL learning activity science is learned as necessary to solve a problem, whereas in DBSL, the science is first taught to the students and then they are engaged in a project.

In the classroom, a student is presented with problem, which then leads to a research activity. Group activities are used in the classroom to build concrete knowledge and a research base of the concept presented. The research can be in the form of a presentation, reading, etc., but the research is teacher led. DBSL activities are carried out on four levels: individual, pairs, groups of four, and the entire class (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004). After the research phase each student is responsible for designing their own solution to the problem. These solutions are then presented to the group and the group selects one or a combination of them. During these activities the instructor critiques each group and provides guidance. During the next phase the groups split and construct a model based on the team's decision about the direction of the project. Next, they present and compare their models to the other half of the group. The group then selects one model and presents it to the class. The class then asks questions and provides the group with feedback on their models.

Inquiry-based learning. Prior to the publication of the *Framework* and the *NGSS*, inquiry-based learning has been perceived as the signature teaching pedagogy of science education (AAAS, 1989; NRC, 1993; NRC, 1996). In the *NSES* inquiry is defined as;

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 1996, p. 23)

During the 1960's Joseph Schwab, suggested that science use inquiry as a way to learn science. He believed science learning should begin with the laboratory instead of ending with it (NRC, 1996, p. 15). He also suggested that science students could ask questions, gather evidence, and propose scientific explanation based on their own explanations (NRC, 1996, p 16). This approach was different from prior approaches in science education where previously students were just engaged in the memorization of science knowledge.

Problem-based learning focuses on having students solve problems by asking questions pertaining to real-world problems. Project-based learning uses long-term complex problems to engage students in real world situations. Design-based learning examines how design can be used to solve real world problems. The intent of inquiry-based learning is to hone in on all types of problem-, project-, and design-based learning methods and combine them into a pedagogical method. These inquiry-based teaching methods engage students in creating, questioning, and revising knowledge, while developing their skills in critical thinking, collaboration, communication, reasoning, synthesis, and resilience (Barron & Darling-Hammond, 2008). The hope is that by using all of these teaching methods interactively students will learn multiple approaches towards addressing problems in science – which may generalize to real-world situations later in life.

Perception of an engineering activity. In the review of the *NGSS* and the *Framework* the term engineering is viewed by the NRC as a practice. The NRC states; “We use the term engineering in a very board sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems” (NRC, 2012, p. 11). Although the practice of engineering is woven throughout the *NGSS* it is difficult to view design-based learning as more than a set of steps that engage students in building something that supports science experimentation. Most of the practices outlined in the standards focus on the design aspect of the engineering process.

In review of the pedagogical practices listed above each differs in their implementation. However, each practice had implied some type of inquiry aspect. In each of these practices group dynamics, feedback, and research of other possible solutions was each an essential element in the utilization of the process. In the *NGSS*, however, these steps are mentioned, but rarely addressed in the student performance expectations. Furthermore, most of the PEs focuses on the designing of something already well-structured in science education. In engineering the focus is on designing a solution to an ill structured problem. Most of engineering design practices utilized in the *NGSS* focus on building more knowledge of science content.

The *NGSS* intent is to utilize engineering practices in the teaching or science content. However the *NGSS* does not provide a methodological framework of how these practices will be used. Therefore in order to successfully carryout the vision of the *NGSS* it is necessary to identify the characteristics of a methodological framework in preparing teacher to intentionally teach science content.

Research in Teacher Preparation.

Studies on identifying characteristics of teacher preparation programs. Prior studies have been conducted for identifying the characteristics of educational frameworks and teacher proficiencies (Bolte, 2008; Na, 2006; Tigelaar, Dolmans, Wolfhagen, & Van der Vleuten, 2004; Wells, 1992). Bolte (2008) used a Delphi study to reach consensus among 114 experts on the major topics and dimensions of modern science. The study revealed that science lessons should be planned with consideration of the needs and interests of students and provided recommendations on the design of modern science and chemistry lessons (Bolte, 2008, p. 344-345).

Na (2006) used an online modified Delphi to reach consensus on future course delivery modes and recommended teaching competencies that would be required for teacher education faculty in future course delivery environments. Na's (2006) study invited 17 educators form drawn from institutions within the National Council for Accreditation of Teacher Education (NCATE) and five other educational technology organizations. The study used open-ended questions in the first round of contact with the participants in order to frame the preceding rounds. The study suggested that, in the future, more universities will be utilizing online resources in the preparation of perspective teachers and the identified the competencies needed by higher education faculty to do so (Na, 2006, p. 97-103).

Tigelaar, Dolmans, Wolfhagen, & Van der Vleuten (2004) study used a Delphi method to validate a framework for teaching competencies for higher education. The study found that after two rounds the shift in ratings among participants was minimal. In conclusion, the study participants reached consensus on 61 out of 104 items (Tigelaar, Dolmans, Wolfhagen, & Van der Vleuten, 2004). The results of this study were then used to develop a framework of teaching competencies and was could be used as a starting point for teacher evaluation in higher education (Tigelaar, Dolmans, Wolfhagen, & Van der Vleuten, 2004).

In 1992, Wells used a Delphi to establish a taxonometric structure for the study of biotechnology. In this study, eight areas of biotechnology and 69 subdivisions were identified (Wells, 1992, p. 125-126). The author concluded that although the instructional objectives would differ in approach, the structure identified would provide educators with consistent content (Wells, 1992, p. 131). The significance of this research led to the establishment of a taxonomy for the study of biotechnology (Wells, 1994). From this is was found that this work increased interest in "bio-related" technology research (Reed & LaPorte, 2015, p. 49) and was pivotal research that determined the biotechnology content found in technology education (Kwon, 2009. p. 17).

Each of these studies has demonstrated the methods and tactics used to conduct a Delphi study. The goal of the current research is to generate a proposed framework of instructional strategies for preparing science educators to implement design-based engineering practices for teaching science. The above studies are similar in scope and collect and analyze the same type of data deemed necessary to answer the question of this research study. In conclusion, the Delphi method will provide a viable research method for this study.

The Delphi method. The origins of the word Delphi stem from Greek mythology. The Oracle at Delphi was a shrine in Greece that people traveled to in order to receive messages from Apollo about the future (Dalkey, 1968, p.8). Although the Delphi Method does not predict the future, it is a forecasting tool. Based on subjective information, the Delphi method is a consensus-building technique that allows researchers to collect separately the opinion of several experts on one specific topic, avoiding the challenges inherent in group discussion (Weaver, 1971). The Delphi Method is based on the assumption that "two heads are better than one, or...n heads are better than one" (Dalkey 1972, p. 15).

The Delphi method was developed in the 1950's from a subsidiary of the McDonald Douglas Corporation and in 1948, with funding from the Ford Foundation, became an independent nonprofit (RAND, 2014). The method was developed by Project RAND (**R**esearch **ANd D**evelopment) during the cold war era and spearheaded by researchers Norman Dalkey and Olaf Helmer (Rescher, 1998, p. 187). The method was first used to gather expert opinions on the amount of A bombs the United States required to strategically annihilate Soviet industrial targets (Dalkey & Helmer, 1963, p. 458). RAND also incorporated methods to study the vulnerability reduction of U.S. retaliatory air power, game theory and military simulations, and information management of deficient or uncertain information (Rescher, 1998, p. 189). In 1964, Helmer and Brown sought to apply the Delhi Method to the study of social issues. *The Long Range Forecasting Study* was the first of these to implement the Delphi Method outside the area of defense. The study focused on identifying long-range trends and issues dealing with the science and technology and the effects the field may have on society (Linstone & Turoff, 1975). The Delphi method has been a tried and acceptable method for qualifying professional judgment and has been employed to gather expert opinion on numerous and diverse topics and concerns in education (e.g., Childress & Rhodes, 2008; Na, 2006; Wells, 1992; Householder, 1990; Custer, Scarcelia, & Stewart, 1999; Clark, 1998). This is a brief history of the Delphi Method and what is demonstrated from this review of literature is the reliability and confidence researchers have in this method.

Delphi methodology implementation procedures. Linstone and Turoff (1975) describe Delphi method as a series of questions or ‘rounds’ interspersed by controlled feedback, which seek consensus of opinion among experts. The Delphi uses a series of questionnaires that are administered by a facilitator to a group of identified experts. The questionnaires are designed to gather individual responses on specific subject matter and allow panel members to refine their views based on the responses of the group. Linstone and Turoff (1975) identify these methods as reflecting a conventional type Delphi.

In traditional Delphi studies described by Linstone & Turoff (1975), the researcher designs a questionnaire that is then is sent to a group of identified experts in the area of concern. The questionnaire is later returned to the researcher where data are connected and a new questionnaire is formed based on the results of the original questionnaire. Listed on this questionnaire are the original responses of the entire group. During the administration of the second questionnaire all respondents are asked to reevaluate their original answers after also considering the group responses. This method is repeated until a consensus is reached. Pfeiffer (1968) outlines three steps to the Delphi:

1. The first questionnaire may instruct the panel to generate a list of opinions involving experiences and judgments, predictions, and recommended activities.
2. On the second round, a copy of the collective list is sent to each expert and the expert is asked to rate or evaluate each item by some criterion of importance.
3. The third questionnaire includes the list, the ratings indicated, and the consensus, if any. The experts are asked to either revise their opinions or discuss their reasons for not joining consensus with the group.

However, Delphi methods have been modified to answer certain research questions that have been modified to the needs of the researcher. In a study entitled *Design-Based Science (DBS) and Student Learning*, Hasson, Dershimer, Krajcik, Marx, and Mamlok-Naaman (2000) reported three different types of Delphi that did not follow the traditional approach: the Modified Delphi, the Policy Delphi and Real Time Delphi. The modified Delphi follows the same procedure as a traditional Delphi but begins with a set of selected items (Custer, Scarcella, & Steward, 1999). This is different from a full Delphi where the beginning question is open-ended. The Policy Delphi is used to assess the degree of consensus among stakeholders with opposing views and identify the divergence of their opinions (Rayens & Hahn, 2000). A Real Time Delphi increases efficacy in the gathering expert response by utilizing computers to conduct and analyze the data of the study (Gordon & Pease, 2006). These types of Delphi are sometimes classified as a *Delphi Conference* (Linstone & Turoff, 1975, p. 5).

Linstone & Turoff (1975) explain that most Delphi studies adhere to four distinct steps (p.5). At the beginning of the Delphi the issue is revealed by each of the panel participants by contributing information they feel is relevant to the subject matter (Linstone & Turoff, 1975, p. 5). The second phase of the study focuses on the process of reaching an understating of how the panel perceives the issue (Linstone & Turoff, 1975, p. 5). In the next phase, rationales for the discrepancies among respondents are explored by the panel members (Linstone & Turoff, 1975, pp. 5-6). In the final phase of the exercise all information gathered is presented and analyzed by the group, which is then fed back to the group for additional consideration (Linstone & Turoff, 1975, p. 6).

Delphi method data collection and validation. Data collection in the use of the Delphi relies on several factors. Brooks (1979) identifies eight steps in the Delphi Method:

1. Identify the panel of experts.
2. Determine the willingness of the individuals on the panel
3. Gathering individual input on the specific issue and then compiling it into basic statements.
4. Analyzing data from the panel.
5. Compiling information on a new questionnaire and sending to each panel member for review.
6. Analyzing the new input and returning to the panel members the distribution of the responses.
7. Asking each panel member to study the data and evaluate their own position based on the responses from the group. When individual responses vary significantly from that of the group norm, the individual is asked to provide a rationale for their differing viewpoint while limitations are placed on the length of the remarks in order to keep responses brief.
8. Analyzing the input, and sharing the minority supporting statements with the panel. Panel members are again asked to review their position and if not within a specified range, to justify the position with a brief statement.

Delphi method limitations. The success of a Delphi study relies on overcoming and recognizing a number of limiting factors. A major limiting factor is risk of diminishing response rates across the administration over multiple rounds. The quality of responses to a Delphi relies heavily on the panel of experts. The selection process of panel members is key to the success of the Delphi. Due to the amount of time a Delphi can take, experts may lose interest in the subject. Linstone and Turoff (1976) raised five common reasons that Delphi studies fail:

1. Imposing monitor views and preconceptions of a problem upon the respondent group by over specifying the structure of the Delphi and not allowing for contribution of other perspectives related to the problem.
2. Assuming that Delphi can be a surrogate for all other human communications in a given situation.
3. Poor techniques of summarizing and presenting the group response and ensuring common interpretations of the evaluation scales utilized in the exercise.
4. Ignoring and not exploring disagreement so that discouraged dissenters drop out and an artificial consensus is generated.
5. Understanding the demanding nature of a Delphi and the fact that the respondents should be recognized as consultants and properly compensated for their time if the Delphi is not an integral part of their job function. (p.6)

A review of other Delphi studies identified these limitations:

1. Poor techniques of summarizing and presenting the group response and ensuring common interpretations of the evaluation scales utilized in the exercise (Linstone and Turoff 1975).
2. Ignoring and not exploring disagreement so that discouraged dissenters drop out and generate an artificial consensus (Linstone and Turoff, 1975).
3. Panel attrition as an issue due to large competency sets, which consume large blocks of time and concentration from the panel members (Custer, Scarcellam & Steward, 1999).

Delphi method rationale. To answer the research question of this study, participants will need to make informed judgments to reach a consensus on the characteristics of this framework.

Linstone and Turoff (1975) state that the "Delphi may be characterized as a method for structuring a group communication process so that process is effective in allowing a group of individuals as a whole, to deal with a complex problem" (p. 3). Linstone and Turoff (1975) also argued that the Delphi can apply to planning university campus and curriculum development and in the design of educational models. In light of these studies, it has been determined that a modified Delphi method would fit best with the current research goals.

The rationale for using a modified Delphi over a traditional Delphi is that it is the intent of this research to gather the data from experts from multiple fields of teacher education; each of these fields may differ in methods and strategies used to prepare future educators. Therefore, in order to initiate the dialog among panel participants, it will be necessary to provide a common reference. In a traditional Delphi, the process begins with an open-ended question administered to a panel of experts. The responses are then summarized and listed on a Likert scale. This is commonly referred to as Round II of the instrument. The participants are then asked to rank the level at which they agree or disagree with a given statement. The procedure continues with multiple rounds until a consensus is reached for the given question. The modified Delphi method differs from the traditional Delphi in that it provides the panel members with a selection of items generated by literature reviews, interviews, and/or related experiences (Custer, Scarcella, & Steward, 1999). To this end, the current study utilizes *NGSS* as a source and reference point for initiating the discussion among participants.

The researcher of this study seeks to identify the characteristics of a methodological framework for preparing science educators to internationally implement design-based engineering practices for teaching science content. Similar Delphi studies (Bolte, 2008; Na, 2006; Tigelaar, Dolmans, Wolfhagen, & Van der Vleuten, 2004; Wells, 1992) have been successful in characterizing educational frameworks. The procedures for implementing this study are executable and within the capabilities of this researcher's experience. Despite some limitations, the study has potential to make a meaningful contribution to the educational community. Although, the proposed study does not seek to find a placement for nuclear weapons as in the RAND study, the stakes are high. The *NGSS* will be used to design curricula to effectively prepare our next generation(s) of students; if care is not taken, generations of ill-prepared students could pay the price.

Summary

In review of the *NGSS*, science education stakeholders' perceptions of what an engineering activity is do not align with what research describes as an engineering design activity. The NRC focuses on the integration of the engineering practices, but does not provide science educators with guidance on how to use the engineering design process in the intentional teaching of science content. The aforementioned design-based learning practices have demonstrated efficacy in the teaching of engineering practices. However, a majority of the student PE's neglect to focus on elements specific to the learning of engineering design. Furthermore, the *NGSS* lacks guidance on how engineering practices should be used to teach science content.

The architects of the *NGSS* believe the teaching of engineering practices is critical to the education of students in science. However, there is still much development that needs to be done in preparing teachers in the use of engineering practices. The *NGSS* is calling for teachers that have knowledge of science facts and the ability to use engineering practices to address a human wants or needs. Currently, science teachers engage students in scientific inquiry and perform experiments that lead to a predetermined outcome. Science education is now intending to use engineering practices in the teaching of science content. This area is largely new to the rest of the science world and will require teachers to have an understanding of engineering practices.

As discussed in previous sections, science education has been focused on content rather than application. Although the NRC has shifted its focus to the practical application of science and engineering the effort has resulted in more content than application when executing engineering. To successfully implement prepare teacher with this vision of the *NGSS,* there is a need to characterize a methodological framework for preparing science educators to implement design-based engineering practices. As supported by this literature review, without these characteristics, science educators will not be prepared to use engineering practices to teach science content. This review also explored examples of research methods of like studies and supports the use of the modified Delphi method for this study.

CHAPTER III: METHOD

This chapter presents and describes the research design, participants, measures and procedure used to investigate the research questions of this study. This study is being conducted to characterize a methodological framework for preparing science educators to implement design-based engineering practices to *intentionally* teach targeted science content. The following research questions guided this study:

RQ1: How should teacher educators prepare K-12 pre-service science teachers to *define engineering* problems as one of eight *NGSS* practices all students should acquire through science education?

RQ2: How should teacher educators prepare K-12 pre-service science teachers to *design engineering solutions* as one of eight *NGSS* practices all students should acquire through science education?

RQ3: How should teacher educators prepare K-12 pre-service science teachers to intentionally teach targeted science content using their newly acquired abilities to define engineering problems and design engineering solutions?

Research Design

The design of this research was based on prior forecasting studies (Bolte, 2008; Na, 2006; Tigelaar, Dolmans; Wolfhagen, & Van der Vleuten; 2004; Wells, 1992) and utilized a panel of experts to characterize the methodological framework for preparing science teachers to implement design-based engineering practices to intentionally teach science content and practices. The forecasting technique followed a modified Delphi method to administer multiple rounds of questionnaires to a panel of science, technology and engineering education experts. The study adhered to the following criteria (Martino, 1975) for conducting Delphi research:

iteration with controlled feedback, anonymity, and statistical representation of group response. Limitations imposed by time, finances, and distance issues related to the geographic dispersion of potential experts necessitated a digital administration strategy that would allow selected experts to participate from their respective distant locations.

Participants

Successful Delphi research is dependent upon the selection of appropriate experts qualified in their respective disciplines. Panelists will not only affect the quality of responses, but the credibility of the research results. The selection process must therefore identify the required qualifications any panel member must meet in order to be considered for participation.

Panel qualifications. To be considered as a potential panelist for the current study each of the participants must have met 3 out of 5 of the following criteria. This approach aligns with other studies of this nature (Na, 2006; Wells, 1992).

1. Expertise in the teaching and learning of K-12 science, technology and/or engineering education.
2. Minimum of five years of teacher preparation experience in higher education in science, technology or engineering.
3. Currently addressing the knowledge, skills and attitudes reflected in the *Next Generation Science Standards* (NGSS Lead States, 2013) in the preparation of pre-service teachers.
4. Recently published or presented K-12 science education teaching and learning research in the field, which focuses on teacher education, curriculum design, and/or teacher training.
5. Demonstrated potential for funding in professional development in the areas of science, technology or engineering.

Participant qualifications were verified by using a questionnaire administered at the end of the study participation agreement (Appendix A). Panel members who did not meet the criteria were excluded from the study.

Panel member sources. The selection of participants for a Delphi study is viewed to be one of the most critical steps in the entire process (Hsu & Sandford; 2007, Hasson, Keeney, & McKenna, 2000). In preparation for the selection of panel members a review of several Delphi studies with related research aims informed the method for selecting panel members (Childress & Rhodes, 2008; Na, 2006; Wells, 1992; Householder, 1990; Custer, Scarcelia, & Stewart, 1999; Clark, 1998). The primary objective of the current Delphi study is to elicit expert opinions and reach consensus on the characteristics of a methodological framework for preparing science educators. Although there are limited criteria in the literature for the selection of participants, it is logical that panelists would have related backgrounds and experiences in regards to the issues discussed (Pill, 1971; Oh, 1974). Furthermore, other studies report that engaging experts from diverse backgrounds yields better quality (Lang, 1995; Powell, 2003; Wallsten, Budescu, Erev, & Diederich, 1997).

Building on methods used in prior research to ensure multiple perspectives on the issue being studied, experts for this study were selected from the disciplines of science, technology, and engineering education. The sources from which potential participants were identified included (a) accredited science teacher preparation programs, (b) technology and/or engineering accredited teacher preparation programs, and (c) practicing science, technology and/or engineering teacher educators. The search for panel members began by searching the websites of the Council for the Accreditation of Educator Preparation (CAEP) (formally NCATE) accredited schools for teacher educators in the disciplines of science, technology and engineering education. This yielded 238 science education and 45 technology and or engineering education programs. A search of each university website was then conducted to identify possible panel members that could possibly meet the study participation criteria. This resulted in the identification of panel pool of 218 possible panel members from science education and 31 possible technology and or engineering panel members. Next a search of the Council on Technology and Engineering Teacher Education (CTETE) directory was conducted to identify additional technology and/or engineering education programs. This search yielded an additional 60 possible panel members bringing the total to 91. The rationale for extending the search of possible panel members in technology and/or engineering education was to provide equal representation of each of these fields. Only programs that had a designated science, technology, or engineering teacher education program were selected for the study (see Appendix B for a listing of universities).

Panel size. According to Dalkey's (1969) research, *An Experimental Study of Group Opinion*, a minimum group size of 16 participants is necessary to yield a significance of error of 0.5 or lower (p.408-406). Linstone and Turoff's 1975 study on the techniques and application of the Delphi method suggests a minimum panel size of ten (p. 86), though Linstone (1978) later suggested that a suitable number should consist of seven panel members (p.296). Delbecq, Van deVen, and Gustafson (1975) indicate that panel sizes from 1 to 13 had a greater error rate than panels of more than 13. Studies suggest optimal panel sizes that range from 15 to 25, with error rates becoming more stable as the size of the panel approaches 25 (Na, 2006, Wells 1992). As these are 'rule-of-thumb' estimates, there is no consensus on an optimal panel size (Hsu & Sandford, 2007). According to Ludwig (1997), panel sizes are "generally determined by the number required to constitute a represented pooling of judgments and the information processing capability of the research team" (p.52). In considering the existing research, a minimum initial panel size of 20 would be considered acceptable for the current study and meet the statistical requirements even when accounting for the potential attrition of several panelists.

Measures

This study was designed to include multiple rounds of questionnaires. In a Delphi study, the number of rounds is dependent on the panelists reaching consensus. Three instruments were used to collect the necessary data for this study. They are identified as Round 1 Questionnaire, Round 2 Questionnaire and Round 3 Questionnaire. The questionnaires were constructed using Google Forms and administered via email. Anonymity was maintained throughout all rounds to keep panel members from influencing others and allowing them to freely express their opinions. The following explains the development of each of the questionnaires.

Round 1 Questionnaire. The Round 1 Questionnaire was designed to address each research question in order and was separated into three sections:

Section 1 – *NGSS* Practice 1: Defining Engineering Problems

Section 2 – *NGSS* Practice 6: Designing Engineering Solutions and

Section 3 – Intentional Teaching of Science Content Through Engineering Practices.

Section 1 and 2 consisted of two open questions. The first question in each of these two sections addressed the competencies pre-service science teachers should possess in order to adequately define engineering problems and design engineering solutions as a practice. The second questions asked panel members to generate instructional strategies they believe teacher educators should use when preparing pre-service teachers. Section 3 addressed only one question, which asked participants to provide the instructional strategies teacher educators should use when preparing K-12 pre-service science teachers to intentionally teach targeted science content through engineering practices. Each of these sections aligns with the each of the three research questions and is designed to provide the content, structure and format to construct the Round 2 questionnaire.

Round 2 Questionnaire. The questionnaire developed for Round 2 of this the Delphi study incorporated a Likert scale to be used in determining the level of agreement between panel members. The Round 2 questionnaire was constructed by listing participant responses from Round 1 together with a corresponding 11-point Likert scale ranging from 0 = strongly disagree to 10 = strongly agree. The level of expertise among panelists demands a scale with sufficient variance between choices of agreement to detect subtle differences of opinion. An 11-point scale was therefore used to provide a level of sensitivity necessary for ensuring adequate dispersion among expert responses needed to detect small changes between rounds. In addition to their rating each of the responses, the Round 2 questionnaire asked panel members to provide a justification for their rating of a given response.

Round 3 Questionnaire. All responses from the Round 2 Questionnaire that did not achieve agreement were carried forward and used to construct the Round 3 Questionnaire. Furthermore, the justification statements from Round 2 were shared anonymously in Round 3 with the other panelists as a means of passively persuading panel members to change their opinion regarding a given response based on other expert opinions. Panel members were also given the opportunity in Round 3 to add further comment with the intention of moving all panel members closer to agreement on items. The number of rounds then continued until the panel reached a consensus on all items as indicated by 75% of the participants falling two points on either side of the median. Clayton, (1997) found Delphi studies going beyond three to four rounds did not result in improved consensus among panelists. Martino, (1975) found that 99% of the participant's changes have been taken into account by the end of round three. All items not having reached consensus by the end of Round 3 would therefore be identified as non-consensus items.

Procedure

Panel member selection. Prior to contacting any potential panel members, details of this study were submitted to the Institutional Review Board (IRB) (Appendix C) at Virginia Tech for approval. The panel member selection procedure began with a search for teacher education programs in the areas of science, technology and/or engineering. The search for participants began with examining accredited institutions with the Council for the Accreditation of Educator Preparation (CAEP). In July of 2013 the National Council for Accreditation of Teacher Education (NCATE) and the Teacher Education Accreditation Council (TECA) were combined into one entity charged to develop the next generation of accreditation standards and performance measures for educator preparation (CAEP, 2015). Prior to this, NCATE was the largest national accrediting body for school colleges and departments of education (Day & Schwaller, 2007). To provide equal representation from each discipline, identification of additional technology and/or engineering education programs was necessary. A search of the Council on Technology and Engineering Teacher Education (CTETE) directory was conducted. CTETE is a leading association for research in technology and/or engineering education.
A listing of all the contacted institutions and departments/personal is provided in Appendix D.

Administration of Round 1 Questionnaire. After identifying all CAEP/NCATE approved science, technology and/or engineering programs, a search was conducted to identify prospective participants within each program. Individuals identified in CAEP/NCATE approved programs were contacted via email and invited to participate as a panel member. Considering the selection criteria stated earlier, invitations were only sent to potential panelists who may have met these requirements. This selection was based on public information found on university websites. The invitation email (Appendix E) provided a brief description of the study, the qualifications necessary to participate in this study and instructions on how to proceed if they were interested. Prospective panel members then self-selected based on their belief they met the requirements to serve on the Delphi panel. As part of the Study Participation Agreement prospective panelists were asked to report their expertise. This information was then verified. Volunteers who did not meet the qualifications were sent notification informing them that based on the information provided, they did not meet the qualifications as a panel member for this study and their service is no longer necessary. The Round 1 Questionnaire consisted of the following four elements: (1) Study Participation Agreement, (2) Round 1 Instructions, (3) Research Introduction and (4) the Round 1 Questionnaire. After completing the Study Participation Agreement via email, participants were provided with Round 1 Instructions and asked to review the Research Introduction and complete the Round 1 Questionnaire. The questionnaire began with a sample response for providing guidance on how to complete the Round 1 Questionnaire. After completing the Round 1 Questionnaire, instructions were provided on how to return responses via email. A sample of the Round 1 Questionnaire is included in Appendix F. Participants were given two weeks to respond to the Round 1 Questionnaire. Panelists who had not returned their questionnaire at the end of week two were sent reminder e-mails. At the end of the third week, panelists who did not return the Round 1 Questionnaire were contacted by phone and asked their intentions for completing the Round 1 Questionnaire.

Development and administration of Round 2 Questionnaire. The open-ended responses collected from the Round 1 Questionnaire provided the content for development of the Round 2 Questionnaire. Using Google Forms, the Round 2 Questionnaire (Appendix G) was constructed to mirror the same three sections used in the Round 1 Questionnaire. The Round 2 Questionnaire opens with a page of brief instructions on how to complete the instrument, followed by three sections containing different sets of items to be ranked. Section One addressed

NGSS Practice 1 (**Defining** *Engineering* **Problems**) and contained items of two types: (1) those minimal competencies all pre-service science teachers must possess to adequately DEFINE engineering PROBLEMS and (2) those strategies teacher educators should use when preparing pre-service teachers with those competencies. Panelists are asked to rank each item on how strongly they believed it should or should not be part of the pre-service preparation for NGSS Practice 1. Section Two addressed *NGSS* Practice 6 (**Designing** *Engineering* **Solutions**) and contained items of two types: (1) those minimal competencies all pre-service science teachers must possess to adequately DESIGN engineering SOLUTIONS and (2) those strategies teacher educators should use when preparing pre-service teachers with those competencies. Panelists are asked to rank each item on how strongly they believed it should or should not be part of the pre-service preparation for *NGSS* Practice 6. In Section Three all items addressed the instructional strategies teacher educators should use when preparing pre-service teachers to intentionally teach targeted science content through engineering practices. Panelists are asked to rank each item on how strongly they believed it should or should not be an instructional strategy used in preparing pre-service science teachers. Panelists were asked to use an 11-point Likert scale to rate their level of agreement with each statements in all 3 sections. A rating of 11 represented the highest level or agreement and 1 the lowest. After completing the Round 2 Questionnaire instructions were provided on how to return responses via email. The respondents were given two weeks after the initial e-mail to respond to the Round 2 Questionnaire. A reminder e-mail was sent out at the end of week two one experts not responding within three weeks were contacted by phone.

Development and administration of Round 3 Questionnaire. The intent of the Round 3 instrument (Appendix H) was to move panelists toward consensus (for or against) on all items. The Round 3 Questionnaire followed the same 3-section format as the two prior questionnaires.

All responses from the Round 2 Questionnaire that panel members did not reach agreement on were listed. Responses from the Round 2 Questionnaire in which panel members agreed were excluded from the Round 3 Questionnaire. Agreement among the panel was measured by calculating the interquartile range (IQR) and median for each of the responses received from the Round 2 Questionnaire. The IQR was used to determine the level of agreement between the opinions of panel members on a given response. A response with 4.0 or less indicated a higher level of agreement among panel members on that item, whereas a response with an IQR greater than 4.0 indicated greater disagreement among panel members. Thus, in alignment with other studies, an IQR equal to or less than 4.0 was selected as the threshold for determining consensus (Na, 2006; Wells, 1992).

Items with consensus were then evaluated to determine whether they should or should not be included in the pre-service preparation for *NGSS* Practice 1 or 6 and/or selected as an instructional strategy used in preparing pre-service science teachers. For this determination, the median response was calculated. Greater medians indicated greater agreement among panelists that items should be included, whereas lower medians indicated greater agreement that items should not be included. In accord with a previous study (Wells, 1992), a median of 7.5 was chosen as a cut-point for determining whether an item should or should not be included.

To this end, any response with a median of 7.5 or higher and an IQR of 4.0 or less indicated that the panelist agreed the item “should be” included in the framework. Items with less than a median of 7.5 and an IQR at 4.0 or less indicate panelist agree the item “should not” be included in the framework. All other items were carried forward to Round 3 (i.e., IQR > 4.0).

Using Google Forms, disagree upon responses were listed on an 11-point Likert scale and customized for each of the panelists. Customization involved communicating to each panelist the frequency and mode on a given item, providing all comments/justifications for that item, as well as their individual rating of that item relative to the entire group. While viewing their rating relative to the group mode they were asked to reconsider their rating and then to either re-rate or confirm their rating. Any panelists who rated an item two points outside of the mode of an item were asked to provide a justification for their decision not to change their rating. Panel members were given two weeks to response to the Round 3 Questionnaire. This method of constructing the Round 3 Questionnaire, using an 11- point Likert scale, is similar to the procedure Na (2006) and Wells (1992) used in determining group consensus and inclusion of items. Submission of the questionnaire and reminder emails followed the same protocol as the prior two instruments.

Establishing stability. Traditionally Delphi studies continue until consensus or stability is reached among the panel members on all responses. Dajani, Sincoof & Taley (1980) stated that studies without group stability are meaningless and stability is considered a necessary criterion in determining consensus. Stability is defined as “the consistency of responses between successive rounds of a study (Dajani et al. 1980, p. 84). In Na’s (2006) study stability was defined as a shift of 15% or less for a single item. For this study the requirement for stability was change in the median of no more than 15% between rounds. Stability was calculated for all responses from Round 3 Questionnaire where consensus was not reached. Items that were stable were recorded as disagreed upon items. If disagreed upon responses from the Round 3 Questionnaire reveal instability between rounds 2 and 3 a Round 4 Questionnaire would have been sent to the panel and the rounds would have continued until consensus was reached.

Timeline of events. It is recommended that panel members be given two weeks to respond to each round (Delbecq, Van de Ven, & Gustafson, 1975). The list presented in Table 1 details the sequence of events in conducting this research. They include: (1) Delphi panel selection, (2) development, and administering of Round 1 Questionnaire, (3) development and administering of Round 2 Questionnaire and (4) development and administering of the Round 3 Questionnaire.

Table 1

Sequence of Administering Delphi

	Developed & Emailed by	Returned by	Type of Collected Data	Method of Analysis
Delphi panel selection	*February 29, 2016*	*N/A*	Panelist Contact Information	CAEP approved Schools
Round 1 Questionnaire	*April 4, 2016*	*April 22, 2016*	Study Participation Agreements, and Pre-Service Preparation for NGSS Practice 1 & 6 and instructional Strategies	List of Pre-Service Preparation for NGSS Practice 1 & 6 and Instructional Strategies needed to Prepare Round 2 Questionnaire
Round 2 Questionnaire	*July 13, 2016*	*September 11 ,2016*	Agreement Level for each Pre-Service Preparation for NGSS Practice 1 & 6 and Instructional Strategy	Determine IQR and Mean for each Response and Prepare Round 3 Questionnaire
Round 3 Questionnaire	*October 18, 2016*	*November 19, 2016*	Defined Agreement Level for each Pre-Service Preparation for NGSS Practice 1 & 6 and Instructional Strategy	Determine IQR and Mean for each Response.

Data Analysis

The following paragraphs present the procedures used to analyze the data collected in each round of this Delphi study.

Round 1 data analysis. The first round data consists of all responses panelists listed in each of the three sections. Specifically, these include all competencies and strategies statements they provided in Sections One (Defining Engineering Problems) and Two (Designing Engineering Solutions), and all strategies statements provided in Section Three (Intentional Teaching). These statements were analyzed to identify those that were identical and those unique. All statements considered to be identical were merged and counted as a single statement. This process resulted in a complete listing of unique statements reflected in each of the three sections. Every statement included in each section became a separate item to be listed and rated in Round 2.

Round 2 data analysis. Data from Round 2 consists of panelists ratings and comments/justification for each item listed in each of the three sections. Ratings for each item were analyzed to calculate the IQR, median, and mode. To determine IQR the distribution was divided into 3 quartiles. Quartile 1(Q1) represented the 25th percentile, 25% of values in this data set were smaller than Q1. The 2nd Quartile (Q2) denotes the 50th percentile; this is also the median of the data set. Quartile 3(Q3) is the 75th percentile of the data set. IQR was calculated by determining the difference between the 25th percentile (Q1) and the 75th percentile (Q3). This value was then used to determine if consensus was reached. Q2 was used to determine the level of agreement among panel members. Below is an example of how IQR was calculated and used in this study to determine consensus between the panel members.

Using and 11-point Likert scale panel members were asked to rate their level of agreement to the following statement: *Teachers must be able to define multiple solutions to a problem that can be solved through the development of an object, tool, process, or system*. Table 1 represents frequency of panel member responses.

Table 2

Panel Frequency

	Level of Agreement	(21) Panel Responses
Strongly Disagree	0	
	1	
	2	
	3	
	4	
	5	
	6	3
	7	4
	8	8
	9	4
Strongly Agree	10	2

The depiction above illustrates there are 3 responses where the panel rated their level of agreement as a 7. This repeats for each of the responses. To begin calculating IQR the data in Table 2 was sorted into an ordered list (Figure 2).

Q1	Median	Q3
6,6,6,7,7,7,7,8,8,8	8	8,8,8,8,9,9,9,9,10,10

Figure 2. Interquartile Calculation

Next the median (8) was found for all of the responses. The difference was then calculated for the middle of the lower quartile (Q1) of the responses and the middle of the upper quartile (Q3). The average was then taken for the middle of the lower quartile (7.0) and for the middle of the upper quartile (9.0). To calculate IQR the average of Q1 (7) is subtracted from the average of Q3 (9). Consensus for this study on any given item was defined by an IQR less than or equal to 4.0. Items with an IQR greater than 4.0 failed to meet consensus. The IRQ of this response is 2, which represents sufficient agreement on this item. A median equal to or greater than 7.50 was used as a cut-point in determining inclusion of that item in the future framework. In the above example, the median was equal to 8.0, which is sufficient for including this item in the framework.

Items that did not reach consensus by these criteria were presented again in Round 3. For each of these items, the mode(s) was calculated. This data is used by individual panel members to compare their previous rating to the most commonly selected rating by the majority of the panel. The comments/justifications for these items were also carried forward and presented. Figure 3 provides an example of a Round 3 question. Notice panel members are provided with a scale to illustrate the concentration of panelists' responses.

SECTION ONE: COMPETENCIES QUESTION

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Response A-14: Define what computational thinking is.

The Multimodal rating for this item is: 1, 4, 5, 8
The most commonly chosen rating/ratings are highlighted in yellow.

Strongly Disagree										Strongly Agree
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	2	1	0	2	2	1	0	2	0	1

Your **Original Rating is** and the blue arrow represents your position on this item.

Panelist Comments: *Please review each comment and reflect on your position shown above relative to the other panelist.*

- *Students should be able to provide activities that require observing, collecting data and then discuss or 'analyze' what the data shows.*
- *Important, but the statement should be reworded to make it more explicit.*
- *I think students understanding of inquiry is related, but not a necessary competency, you can teach this to students through their participation in an engineering activity, not separate.*
- *I don't see how this is a required competency for defining engineering problems.*
- *Important if applied to engineering problems. But does not always occur in engineering design.*

A 14 New Response:
Re-rate your response either the same or differently based on other panelists comments listed above.

Strongly Disagree — *Strongly Agree*
○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Comments:

Figure 3. Round 3 Questionnaire Example

Round 3 data analysis. Data from Round 3 consisted of all items not meeting consensus in Round 2. Panel members were provided with the mode(s) of the panel ratings with their own rating and any comment/justifications given by panelists for that item. They were then asked to review other panel members' comments/justifications and invited to re-rate or confirm their response based on these data. The purpose of providing this information was to passively persuade individual panel members to move closer towards the mode. Ratings for each item were then analyzed to calculate the IQR and median scores. An IQR equal to or greater than 4.0 was again used to indicate an acceptable level of consensus. Among items meeting consensus, a median score equal to or greater than 7.50 represented items considered important to the panel. Both of these criteria (i.e., IQR and median cut-points) were necessary for an item to be recommended for the framework.

CHAPTER IV: RESULTS

The purpose of this Delphi study was to characterize an expert-informed methodological framework for preparing science educators to implement design-based engineering practices to intentionally teach targeted science content. This chapter presents analysis of the data generated in the Delphi study. This analysis was conducted in an effort to answer the research questions presented in Chapter I.

RQ1: How should teacher educators prepare K-12 pre-service science teachers to *define engineering* problems as one of eight *NGSS* practices all students should acquire through science education?

RQ2: How should teacher educators prepare K-12 pre-service science teachers to *design engineering solutions* as one of eight *NGSS* practices all students should acquire through science education?

RQ3: How should teacher educators prepare K-12 pre-service science teachers to intentionally teach targeted science content using their newly acquired abilities to define engineering problems and design engineering solutions?

Delphi Panel Respondents

As discussed in Chapter III the administration of this Delphi study began with sending the Invitation e-mail (see Appendix E) to 218 science teacher educators and 91 technology education teacher educators. The recruitment target of twenty participants (about 6.5% of the pool) was reached within two weeks of the email solicitation. All twenty volunteers met prescribed expertise and professional qualifications. The panel was comprised of eight science teacher educators (7 female, 1 male) and twelve (1 female, 11 male) were technology teacher educators, all of whom competed the first round questionnaire (Appendix F).

Twelve teacher educators (3 science and 9 technology) responded to the Round 2 Questionnaire (Appendix G), and of these only 10 completed the Round 2 Questionnaire in its entirety. Thus the response rate for Round 2 was 50%. The two respondents who did not complete the Round 2 Questionnaire (1 science and 1 technology expert) only completed the first question of Section #1.

All twelve panelists who participated in Round 2 completed the Round 3 Questionnaire. The two panel members who only responded to the first question of Section#1 were sent an abbreviated questionnaire that asked these experts if they would like to adjust only the items they responded to during Round 2. Both of these panel members agreed and completed the abbreviated Round 3 Questionnaire. This resulted in an additional two participants for the first question in Section 1. Table 3 presents a summary of the number of participants for each round and for each question.

Table 3

Number of Panel Participants Per Question Per Round

Delphi Round	Section/Practice/Question	Educator	
		Science	Technology
Round 1			
	Section 1. Question A - Practice 1 Competency	8	12
	Section 1. Question B - Practice 1 Strategy	8	12
	Section 2. Question A - Practice 6 Competency	8	12
	Section 2. Question B - Practice 6 Strategy	8	12
	Section 3. Question - Instructional Strategies	8	12
Round 2			
	Section 1. Question A - Practice 1 Competency	3	9
	Section 1. Question B - Practice 1 Strategy	2	8
	Section 2. Question A - Practice 6 Competency	2	8
	Section 2. Question B - Practice 6 Strategy	2	8
	Section 3. Question - Instructional Strategies	2	8
Round 3			
	Section 1. Question A - Practice 1 Competency	3	9
	Section 1. Question B - Practice 1 Strategy	2	8
	Section 2. Question A - Practice 6 Competency	2	8
	Section 2. Question B - Practice 6 Strategy	2	8
	Section 3. Question - Instructional Strategies	2	8

Note. Each round was comprised of 3 sections. In sections #1 and #2 panelists were presented two questions; in Section #3 panelists were only presented with 1 question.

Round 1 Data Analysis

Theme Analysis for Open-Ended Responses

As stated in the literature review of this study, Round 1 of a traditional Delphi study begins with an open-ended question. The responses are then compiled in a list which is sent to all panelists. During Round 2, the panelists are asked to indicate their level of agreement with each response statement, and are given the opportunity to comment on each item. This procedure then continues for as many rounds as necessary for the panel to reach consensus or stability on the initial questions. The administration of this Delphi study required three rounds to reach consensus or stability on all items.

During all three rounds of the Delphi each questionnaire was separated into 3 sections. Table 4 presents the organization of sections and the panelists' questions. As an open-ended questionnaire, the first round of this Delphi study is different from the other two rounds. Therefore data analysis results from Round 1 respondents are presented first. Results of data analysis for Rounds 2 and 3 of the Delphi are similar in format and therefore presented together by section of the questionnaire. For example, data gathered in "Section 1" of Rounds 2 and 3 are analyzed and presented together. Analysis of data from Section 2 of Rounds 2 and 3 are then presented, followed by Section 3 of Rounds 2 and 3.

Table 4

Questions within each Section of the Delphi Questionnaires

Section 1. Defining Engineering Problems

Question A Practice 1 Competency (Sec1-QA)

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Question B - Practice 1 Strategy (Sec1-QB)

What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DEFINING engineering PROBLEMS*** (strategies used to prepare them to teach that practice)?

Section 2. Designing Engineering Problems

Question A- Practice 6 Competency (Sec2-QA)

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DESIGN engineering SOLUTIONS*** as a practice they would teach students?

Question B - Practice 6 Strategy (Sec2-QB)

What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DESIGNING engineering SOLUTIONS*** (strategies used to prepare them to teach that practice)?

Section 3. Intentional Teaching

Question - Instructional Strategies (Sec3-Q Strategy)

What instructional strategies should teacher educators use when preparing K-12 pre-service science teachers to ***intentionally teach targeted science content*** through engineering practices to (strategies used to prepare them to intentional teach science content through that practice)?

Note. All three rounds follow the same organizational format in each questionnaire.

Practice 1 - Defining Engineering Problems: Section 1 Results

Section 1 of the Round 1 Questionnaire focuses on gathering data in response to Research Question 1 (RQ1: How should teacher educators prepare K-12 pre-service science teachers to *define engineering* problems as one of eight *NGSS* practices all students should acquire through science education?). Practice 1 of the *NGSS* stipulates that all K-12 science teachers should have the ability to define engineering problems as a practice they would teach and that all their students should be able to do. The intent of these questions was to identify the competencies all K-12 pre-service science teachers should possess in order to define engineering problems and the strategy/strategies teacher educators should use when preparing them to teach this practice.

Round 1 open ended responses. Presented below in Table 5 is an example of the open ended responses collected from Round 1. This raw data, from Sec1-QA, illustrates how some experts chose to list one or more teaching competencies while others provided detailed and in depth explanations of the necessary competencies. In order to maintain anonymity among panelists, each expert was assigned a unique identification number. The identification number was followed by either "S" signifying a science expert or "T" signifying a technology expert. Appendix I provides a complete listing of all Round 1 unedited responses.

Table 5

Example of Round 1 (Sec1-QA) Open Ended Responses

Educator	Unedited Responses
1T	Identify and clarify the problem, ask questions, identify the constraints, carefully analyze the problem and break it into small parts, and determine what exactly needs to be done.
2T	1. must understand the 'engineering process' 2. determine the 'problem' 3. determine what do students 'need to know' to solve the problem 4. develop possible solutions based on their research 5. work in small groups in a cooperative manner

Table 5

Example of Round 1 (Sec1-QA) Open Ended Responses

Educator	Unedited Responses
3T	1. They must have a clear understanding and knowledge of the "T&E" components of STEM. At a minimum, they must know technology is about modifying the natural world to meet human needs and wants and engineering applies math and science to create technology. 2. They must know the engineering design process is used in engineering and technology to solve open-ended real-world problems. Although there are many variations, they should be able to describe the basic steps in the engineering design process. 3. They should be able to identify the educational standards that are used in each of the STEM fields. 4. Given a matrix listing the STEM areas, pre-service teachers should be able to identify concepts and practices that occur in each of the areas, especially in those practices and content related to technology and engineering education.

Table 5 (continued)

Example of Round 1 (Sec1-QA) Open Ended Responses

Educator	Unedited Responses
4T	Teachers must be able to situate problems within an authentic real-world context. Teachers must be able to identify restrictions or constraints for design challenges. Teachers must be able to define engineering problems as design challenges that can be solved.
5S	In order to define engineering problems as a practice they would teach students, K-12 pre-service science teachers must be able to: 1. Distinguish the difference between science questions and engineering problems. 2. Identify the critical content and skills objectives of a standard in order to intentionally focus the development of engineering problems during a lesson. 3. Make scientific observations of phenomenon and formulate multiple ideas, questions and problems related to those observations. 4. Determine which scientific questions may be addressed using engineering practices. 5. Articulate engineering problems in a way that implies knowledge of engineering practices. 6. Identify real world contexts that may be used as context for engineering applications of scientific principles.
6T	1. Understanding of how engineering is different from science. 2. Understanding that engineering is both a technological process as well as a professional discipline. 3. The ability to think logically. 4. Recognize that there are several engineering fields that focus on specific issues. 5. Identify what general education aspects of engineering are appropriate for K-12 students. 6. They must sacrifice some of their science preparation for engineering courses so that they would have some of the pre-requisite skills, like working with testing equipment; general tools and machines, and so forth.
7T	1. Understand the engineering design process and various models of the engineering design process. 2. Understand the difference between engineering design and scientific inquiry. 3. Have gone through and experienced a true engineering design based problem before.
8S	Teachers must be able to understand and define inquiry, scientific processes and computational thinking. They should be able to make observations and assess student understanding based on these concepts as well.
9S	1. Read for contextual clues. 2. Prepare teaching materials that provide contextual clues to engineering based

Table 5 (continued)

Example of Round 1 (Sec1-QA) Open Ended Responses

Educator	Unedited Responses
	problems. 3. Identify student level of reading comprehension.
10S	Teachers must be able to identify what counts as an engineering problem (i.e., a problem can be solved using accessible material and equipment), explain to students what makes a problem an engineering problem, and construct opportunities that allow students to take risks and explore multiple trials in an attempt to identify possible paths to solutions
11T	Be able to explain or define what engineering is and what engineering means Be able to provide examples of engineering and engineering problems that will be meaningful to and understood by their students Understand the concepts of parameters, constraints, and specifications, and be able to explain these in age-appropriate ways to students Select engineering design scenarios or challenges purposefully, with the goal of selecting those that enable application of scientific concepts germane to the grade level curriculum, and that are within the students' range of capability
12S	Have to understand what engineers do in their jobs and the diversity of engineering jobs. They have to know how science and engineers work together and how they are different (knowledge vs application). They should experience content embedded engineering activities, should understand how to teach content as well as engineering practices.
13T	Understand what an engineering problem "is" Understand the field of engineering and how engineering problems are different from experimental problems. They should be able to adequately define problems themselves.
14T	Please note that this comes from a current NSF project where we are developing teaching standards for engineering design Dr. David Crismond (dcrismond@ccny.cuny.edu) is our lead researcher. Standard 2. Informed Design Practices When teaching engineering design, teachers facilitate students' development of engineering design thinking and practices. In doing this, teachers provide students with opportunities to: 1. Understand Challenge – Understand the design challenge by identifying desired performances, criteria and constraints. 2. Research & Investigate – Do research and hands-on investigations to gather insights/information about the challenge.
15T	Clearly and succinctly define a problem that can be solved via technical means. Distinguish the difference between problem statements and their solution. Solve problems related societal needs utilizing an iterative design/problem solving process.

Table 5 (continued)

Example of Round 1 (Sec1-QA) Open Ended Responses

Educator	Unedited Responses
	Identify the impacts some problem solutions may have.
16S	1. Understanding of the shifts in the *NGSS* as indicated in the Framework for K-12 Science Education. 2. Realization that giving students design challenges, (instead of have students define the criteria and the constraints), diminishes students' opportunities to learn and apply their science understandings. 3. Ability to identify situations/scenarios that lend themselves to students defining a problem. Situations should be relevant, observable, specific and apply DCIs in the life, earth and physical sciences. For example, if a lake has dying fish...this is the situation/scenario. Students would need to apply their understanding of the DCIs to define what is causing the fish to die, ie. chemicals, food web? Or if it is too hot in the room, students would need to decide what is causing the discomfort, ie. lack of ventilation, shade, personal preference. Possible solutions will vary depending on how students define the problem.
17S	1. The differences and similarities between science and engineering. 2. Focus of engineering on a practical solution to a problem. 3. Engineering requires science content knowledge but also knowledge of other areas--like economics, human impact, safety. 4. Describe and use a model of the engineering process, and that this process differs from the scientific method.
18T	Understand constraints, tradeoffs, problem definition, personal beliefs and how they influence a design. Being able to write out or explain a problem is paramount. Knowing how to access information that is relevant to the problem; this can be electronic sources as well as human. Knowing how to ask questions.
19S	1. Apply Design, Engineering and Technology Literacy Standards content knowledge and skills to the designing and implementation of DTE learning activities. 2. Design instructional environments that that accommodate inquiry-based pedagogies, meet institutional goals of sustainability, are welcoming destinations, and support interdisciplinary collaborations. 3. Implement and analyze STEM learning experiences regarding their focus on State Curriculum Standards for Mathematics, Science, Technology, and Engineering–Grades K-8. 4. Implement Design, Technology and Engineering Education Instructional Methods & Strategies in technology and engineering and STEM focused curricular applications. 5. Apply STEM pedagogical concepts, in Design, Technology and Engineering Education in STEM focused curricular models.

Table 5 (continued)

Example of Round 1 (Sec1-QA) Open Ended Responses

Educator	Unedited Responses
20T	Distinguish problems that require engineering solutions. Clarify criteria. Define constraints. Demonstrate safe use of tools. Model ethical research procedures. Communicate a structured process for investigating engineering problems.

Note. Information which could potentially identify the expert was removed from the statements of two panelists.

Proceeding with this Delphi study required the consolidation of similar statements made by different panelists into unique items which could be listed and ranked in subsequent rounds. To accomplish this each panelist's statement was analyzed for like themes. Themes that were identified as substantially the same were combined into a single item in Round 2. Unique themes (i.e., those offered by only one of the twenty panelists) were not altered for Round 2. Below explains the consolidation process followed by the presentation of results from theme analysis for Sec1-QA which ultimately yielded 80 items that were then presented in Section 1 of Round 2.

Question A: Competency

Round 1 theme analysis. Question A (Sec1-QA) asked panelists to respond to the following guiding question:

> <u>Question A:</u> What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Each statement was separated into its constituent sentences. The researcher, together with another expert in the field, searched for keywords that identified a competency within that sentence. Within each sentence, keywords were bolded to identify the competency/or competencies addressed in that statement. Sentences with multiple competences were listed twice in order to independently reflect each, along with the corresponding theme. Table 6 provides an example of the analysis used for identifying *NGSS* Practice 1 Competency themes for Sec1-QA. This same process was used for each of the remaining sections. Please see Appendix J for a complete listing of all Round 1 identified themes.

Table 6

Example Round 1(Sec1- QA) Practice 1 Competency Theme Analysis

Educator	Competency Identification	Identified Theme
1T	**Identify** and clarify the **problem**, ask questions,	Problem Identification
	Identify and **clarify** the **problem**, ask questions,	Problem Analysis
	Identify the **constraints**	Constraint Identification
	Carefully **analyze** the **problem**	Problem Analysis
	Break it into **small parts**, and determine what exactly needs to be done.	Break Problem Into Smaller Parts
	Break it into small parts, and **determine** what exactly needs to be done.	Develop Solutions
2T	Must understand the **'engineering process'**	Understand Engineering as a Process
	Determine the **'problem'**	Problem Identification
	Determine what do students **'need to know'** to solve the problem	Identify Grade & Age Appropriate Content
	Develop possible **solutions** based on their research	Develop Solutions
	Work in small **groups** in a cooperative manner	Group Work
3T	At a minimum, they must **know technology is about** modifying the natural world to meet human needs and wants	Define Technology
	Engineering applies math and science to create technology.	Understand the Vocation of Engineering
	They must **know** the **engineering design process** is used in engineering and technology	Understand Engineering as a Process
	Solve open-ended **real-world problems**.	Utilize Real World Examples
	Although there are many variations, they should be able to **describe** the basic steps in the **engineering design process**	Describe Engineering Process
	They should be able to **identify** the **educational standards** that are used in each of the STEM fields.	Identify Educational Standards
	Given a matrix listing the STEM areas, pre-service teachers should be able to **identify concepts** and practices that occur in each of the areas	Identify STEM Concepts
	Given a matrix listing the STEM areas, pre-service teachers should be able to **identify** concepts and **practices** that occur in each of the areas	Identify STEM Practices

Table 6

Example Round 1(Sec1- QA) Practice 1 Competency Theme Analysis

Educator Competency Identification	Identified Theme
Given a matrix listing the STEM areas, pre-service teachers should be able to **identify concepts** and practices that occur in each **of the areas** especially in those practices and content related to technology and engineering education.	Identify Concepts of other areas of Academia, such as Economics, Engineering, Human Impact, Safety, & Technology

Note. Panelists' statements containing multiple competency themes are listed more than once.

Identified competency themes found to be repeated among panel members were then grouped. Each competency theme was cross-listed with the panel member number to identify from whom the statement originated. Table 7 is a demonstration of the development of three Round 2 competency statements. Appendix J provides a complete listing of Round 2 statement development.

Table 7

Development of Round 2 (Sec1-QA) Practice 1 Competency Statements

Competency Theme	Educator ID	Original Statement	Rationale	Round 2 Competency Statement
Ability to do Hands on Investigations	14 T	Research & Investigate – **Do** research and **hands-on investigations** to gather insights/information about the challenge.	The panel member used the statements **hands on, and investigation**. The content of these statements addresses ability to do hands on investigations.	do hands on investigations to gather insights/information about engineering design challenges.
Ability to Explain Engineering Problems	10 S	**Explain** to students what makes a problem an **engineering problem**	Panel members used the statements **explain, communicate, identify, engineering problems**. The content of these statements addresses PST ability to communicate in spoken form.	explain engineering problems.
	10 S	Teachers must be able to **identify** what counts as an **engineering problem** (i.e., a problem can be solved using accessible material and equipment),		
	18 T	Being **able** to write out or **explain** a **problem** is paramount.		
	20 T	**Communicate** a structured process for investigating **engineering problems.**		
Ability to Identify Multiple Solutions	10 S	Explore **multiple** trials in an attempt to **identify** possible paths to **solutions.**	The panel member used the **statements multiple, identify and solutions.** The content of this statement addresses PST ability to identify multiple solutions.	identify multiple solutions to an engineering problem.

Note. Bolded words are used to form the Round 2 Statement. Round 2 Competency statements were worded to fit the question stem of the Round 2 Questionnaire.

Round 1 resulted in a list of 80 competencies, each suggested by one or more panelist as essential all K-12 pre-service science teachers must possess (know and be able to do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students. These 80 items (Table 8) represented about 19% of the 428 items on the Round 2 Questionnaire.

Table 8

Round 2 (Sec1-QA) Practice1 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DEFINING engineering PROBLEMS*** all K-12 pre-service teachers must be able to:
A-1	do hands on investigations to gather insights/information about engineering design challenges.
A-2	explain engineering problems.
A-3	identify multiple solutions to an engineering problem.
A-4	research solutions to an engineering problem.
A-5	explain engineering design problems in written form.
A-6	ask questions about engineering problems.
A-7	analyze STEM learning experiences regarding their focus on state curriculum standards.
A-8	apply Disciplinary Core Ideas.
A-9	demonstrate logical thinking when planning engineering tasks.
A-10	apply STEM pedagogical concepts, in design, technology and engineering education in STEM focused curricular models.
A-11	assess student understanding of inquiry, scientific processes and computational thinking through observations.
A-12	break engineering problems into smaller parts.
A-13	read engineering design problems for contextual clues.
A-14	define what computational thinking is.
A-15	define the constraints of engineering problems.
A-16	define a engineering problem.

Table 8

Round 2 (Sec1-QA) Practice1 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DEFINING engineering PROBLEMS*** all K-12 pre-service teachers must be able to:
A-17	define a science problem.

Table 8 (continued)

Round 2 (Sec1-QA) Practice 1 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DEFINING engineering PROBLEMS*** all K-12 pre-service teachers must be able to:
A-18	define the meaning of scientific inquiry.
A-19	demonstrate that technology is about modifying the natural world to meet human needs and wants.
A-20	define the meaning of engineering.
A-21	define what engineering is.
A-22	describe the basic steps of the engineering design process.
A-23	design instructional environments that accommodate inquiry-based pedagogies.
A-24	prepare teaching materials that provide contextual clues to engineering based problems.
A-25	determine which scientific questions may be addressed using engineering practices.
A-26	develop solutions to engineering problems.
A-27	differentiate between the practices of scientific inquiry and engineering design.
A-28	embed engineering activities into science content.
A-29	explain how the engineering process differs from the scientific method.
A-30	explain the meaning of engineering.
A-31	explain what engineering is.
A-32	facilitate student development in engineering design practices.
A-33	focus on practical engineering solutions to a problem.
A-34	work in small cooperative groups.
A-35	identify the concepts that occur in economics, engineering, human impact, safety, and technology and how they related to technology and engineering education.
A-36	identify the constraints on an engineering problem.
A-37	identify engineering design criteria.
A-38	identify engineering design performances.
A-39	identify the critical content and skills objectives of an educational standard in order to intentionally focus the development of engineering problems during a lesson.

Table 8 (continued)

Round 2 (Sec1-QA) Practice 1 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DEFINING engineering PROBLEMS*** all K-12 pre-service teachers must be able to:
A-40	identify engineering problems that require engineering solutions.
A-41	identify grade and age appropriate engineering content.
A-42	identify interdisciplinary connections to engineering.
A-43	identify how personal beliefs influence design.
A-44	identify other practices of academia, such as economics, human impact, and safety, and relate them to practices of engineering and science.
A-45	identify the technology and engineering concepts of each in the STEM fields.
A-46	identify the technology and engineering practices in each of the STEM fields.
A-47	implement design based strategies in technology and engineering and STEM focused curricular applications.
A-48	implement design based instructional methods in technology and engineering and STEM focused curricular applications.
A-49	implement STEM learning experiences according to state standards.
A-50	implement technology and engineering instructional methods.
A-51	implement technology and engineering instructional strategies.
A-52	make scientific observations to formulate multiple ideas, questions and problems related to those observations.
A-53	meet the institutional goals of sustainability.
A-54	model the engineering process to demonstrate that this process differs from the scientific process.
A-55	model ethical research procedures.
A-56	analyze engineering problems.
A-57	identify engineering problems.
A-58	take risk when solving engineering problems.
A-59	provide meaningful examples of engineering and engineering problems that will be understood by their students.
A-60	select grade and age appropriate engineering design scenarios and challenges that enable the application of scientific concepts.

Table 8 (continued)

Round 2 (Sec1-QA) Practice 1 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DEFINING engineering PROBLEMS*** all K-12 pre-service teachers must be able to:
A-61	define a problem that can be solved using technical means.
A-62	use the engineering design process to solve a problem.
A-63	understand computational thinking.
A-64	understand the concepts of grade and age appropriate engineering activities.
A-65	identify the desired performances, criteria and constraints of an engineering design challenge.
A-66	understand the design constraints of an engineering problem.
A-67	understand the design tradeoffs of an engineering problem.
A-68	understand Disciplinary Core Ideas.
A-69	understand engineering as a process.
A-70	understand engineering problems.
A-71	understand the Framework for K-12 Science Education.
A-72	understand how to teach engineering practices.
A-73	understand how to teach science content.
A-74	understand the shifts in *NGSS* as indicated in the Framework of K-12 Science Education.
A-75	understand scientific inquiry.
A-76	understand the vocation of engineering.
A-77	utilize educational standards in the development of engineering problems.
A-78	utilize an iterative design process to solve societal problems.
A-79	utilize real world examples when solving engineering design problems.
A-80	utilize engineering tools and instruments.

The method of theme analysis used to produce this set of 80 questions was then repeated for the remaining sections of the study (see Table 4). Presented next are the results of the theme analysis for Section 1, Question B.

Question B: Strategy

Round 1 theme analysis. Question B (Sec1-QB) asked the panelists to respond to the following guiding question:

> Question B: What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DEFINING engineering PROBLEMS*** (strategies used to prepare them to teach that practice)?

The theme analysis for Question B resulted in 102 instructional strategies (Table 9). These represented 23.8% of the 428 Round 2 items, making Sec1-QB the largest section of the Round 2 Questionnaire.

Table 9

Round 2 (Sec1-QB) Practice 1 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DEFINE engineering PROBLEMS*** teacher educators should engage their students in:
B-1	administering problem-based engineering activities.
B-2	analyzing engineering case studies.
B-3	developing problem-based learning activities and lessons that require students to apply engineering concepts.
B-4	applying engineering practices.
B-5	developing problem-based learning activities and lessons that require students to apply scientific concepts.
B-6	developing problem-based learning activities and lessons that require students to apply scientific practices.
B-7	creating authentic engineering activities.
B-8	creating authentic science activities.
B-9	brainstorming engineering activities.

Table 9

Round 2 (Sec1-QB) Practice 1 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DEFINE engineering PROBLEMS*** teacher educators should engage their students in:
B-10	designing and building a technical device that solves an engineering problem.
B-11	collaborative critique of engineering design resources.

Table 9 (continued)

Round 2 (Sec1-QB) Practice 1 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DEFINE engineering PROBLEMS*** teacher educators should engage their students in:
B-12	collaborative engineering design activities.
B-13	collaborative engineering learning activities.
B-14	collaboratively aligning science and engineering lessons to the NGSS.
B-15	comparing and contrasting the science approach to the engineering approach in order to solve the same problem.
B-16	computational thinking science activities.
B-17	conducting curriculum inventories to identify potential areas to utilize engineering design.
B-18	contextualizing scientific phenomena to determine whether it involves a problem of engineering design.
B-19	cooperative learning activities.
B-20	defining engineering problems.
B-21	defining scientific questions.
B-22	demonstrating the difference between scientific inquiry and engineering design.
B-23	demonstrations of laboratory practices used in technology and engineering.
B-24	demonstrating ethical research procedures.
B-25	describing the purpose of integrative STEM education.
B-26	design-based lessons to modeling the practices identified in the NGSS.
B-27	design-based pedagogical approaches intentionally to teach the content and practices of science and mathematics education through the content and practices of technology/engineering education.
B-28	designing age and grade appropriate inquiry/design based instructional models.
B-29	designing hands-on problem solving lessons in science and engineering.
B-30	designing technical devices to solve engineering problems.
B-31	determining to involve engineering design in science problems.
B-32	developing knowledge of technical skills.
B-33	developing technological problem statements.

Table 9 (continued)

Round 2 (Sec1-QB) Practice 1 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DEFINE engineering PROBLEMS*** teacher educators should engage their students in:
B-34	developing problem-based learning activities that requires students to apply both scientific and engineering concepts and practices.
B-35	development of engineering design challenges.
B-36	differentiating between scientific inquiry and engineering design.
B-37	differentiating problem based learning and project based learning.
B-38	discussing engineering case studies.
B-39	discussing concepts of the *NGSS* and how engineering design practices should be embedded within the curriculum.
B-40	peer discussions on the conceptual shifts of K-12 Science Framework.
B-41	distinguishing science problems that require engineering solutions.
B-42	documenting engineering design solutions.
B-43	embracing ambiguity and guiding students towards a understanding of a problem.
B-44	hands-on engineering design activities.
B-45	hands-on problem solving activities.
B-46	identifying the technological/engineering constraints of engineering problem.
B-47	identifying the technological/engineering criteria of an engineering problem.
B-48	identifying technological/engineering problems.
B-49	identifying design constraints due to available materials or class time.
B-50	identifying engineering problems.
B-51	identifying science questions.
B-52	identifying the vocation of engineering.
B-53	interdisciplinary STEM teams to solve engineering problems.
B-54	introducing educational resources such as the NGSS.
B-55	isolated scientific phenomena to determine if it involves engineering design problem.

Table 9 (continued)

Round 2 (Sec1-QB) Practice 1 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DEFINE engineering PROBLEMS*** teacher educators should engage their students in:
B-56	keeping a journal.
B-57	facilitated science and engineering lessons.
B-58	making connections between science and engineering concepts.
B-59	making connections between science and engineering practices.
B-60	making scientific models.
B-61	modeling the utilization of science materials.
B-62	modeling scientific inquiry practices.
B-63	modeling safe technology and engineering tool use.
B-64	open-ended, multiple solution engineering problems.
B-65	participating in science lessons as students.
B-66	peer evaluations of curriculum focused on the defining of engineering problems.
B-67	practicing project based engineering learning challenges.
B-68	presentations on scientific phenomena.
B-69	presentations using scientific experiences.
B-70	presentations using scientific models.
B-71	problem based engineering activities.
B-72	design based engineering instruction.
B-73	developing engineering prototypes.
B-74	providing feedback to K-12 students.
B-75	reading the K-12 science Framework.
B-76	reflecting on the environmental safety, economical, and human impact constraints of a science problem.
B-77	researching the engineering design processes.
B-78	reviewing engineering case studies.

Table 9 (continued)

Round 2 (Sec1-QB) Practice 1 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DEFINE engineering PROBLEMS*** teacher educators should engage their students in:
B-79	scientific inquiry activities.
B-80	teaching mini engineering lessons to their peers.
B-81	applying technological/engineering design pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education.
B-82	appropriate instructional strategies to engage students in the engineering design-processes.
B-83	using argumentation skills.
B-84	using case studies.
B-85	using data analysis.
B-86	using data collection.
B-87	using differentiated instruction to teach engineering design.
B-88	using formative assessments to gather evidence of students' learning, provide timely feedback, and adjust daily instruction.
B-89	group discourse.
B-90	using hands on learning experiences in students own discipline (bio, Chemistry, physics).
B-91	using instructional strategies to monitor student progress of engineering design concepts.
B-92	using integrative engineering design based instructional strategies.
B-93	using performance rubrics to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.
B-94	using summative assessments to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.
B-95	concept mapping.
B-96	cooperative learning activities so students can see how teams are vital to the success of an engineering project.
B-97	utilizing engineering design exemplars.
B-98	media presentations of exemplary science and engineering instruction.

Table 9 (continued)

Round 2 (Sec1-QB) Practice 1 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DEFINE engineering PROBLEMS*** teacher educators should engage their students in:
B-99	utilizing peer sharing to present findings in an effective manner.
B-100	utilizing peer sharing.
B-101	utilizing science content to work through engineering models.
B-102	writing lessons focusing on modeled pedagogy.

Practice 6 - Designing Engineering Solutions: Section 2 Results

Section 2 of the Round 1 Questionnaire was focused on gathering data in response to Research Question 2 (RQ2: How should teacher educators prepare K-12 pre-service science teachers to *design engineering solutions* as one of eight *NGSS* practices all students should acquire through science education?). Practice 6 of the *NGSS* requires all K-12 teachers have the ability to design an engineering solution to solve a problem using a systematic process to define a problem and then generate, test and improve their solution (*NRC*, 2013. p.11). Presented below are the results of the theme analysis for Section 2, Questions A and B.

Question A: Competency

Round 1 theme analysis. Question A (Sec2-QA) asked participants to respond to the following guiding question:

> Question A: What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DESIGN engineering SOLUTIONS*** as a practice they would teach students?

The theme analysis of this question resulted in a total of 89 Round 2 competency statements (Table 10), accounting for about 21% of the 428 total items on the Round 2 Questionnaire.

Table 10

Round 2 (Sec2-QA) Practice 6 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DESIGING engineering SOLUTIONS*** all K-12 pre-service teachers must be able to:
A-1	explain science problems in written form.
A-2	analyze engineering design solutions.
A-3	analyze scientific data.
A-4	choose an engineering design solution.
A-5	do hands on engineering prototyping activities.
A-6	identify multiple solutions to an engineering problem.
A-7	design and test engineering prototypes.
A-8	utilize debugging to solve engineering problems.
A-9	utilize feedback to refine engineering prototypes.
A-10	adapt prior engineering design solutions.
A-11	adapt prior technologies.
A-12	add additional content to and engineering problem in an effort to find a solution.
A-13	analyze STEM learning experiences regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.
A-14	apply contextual reading skills.
A-15	apply design, engineering and technology literacy standards in the design and implementation of DTE learning activities.
A-16	demonstrate logical thinking in the design of engineering activities.
A-17	apply STEM pedagogical concepts in design, technology and engineering education in STEM focused curricular models.
A-18	augment engineering problems in an effort to solve it.
A-19	combine elements of engineering problem in an effort to solve it.
A-20	combine techniques of engineering problem in an effort to solve it.

Table 10

Round 2 (Sec2-QA) Practice 6 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DESIGING engineering SOLUTIONS*** all K-12 pre-service teachers must be able to:
A-21	share engineering design ideas and solutions to reflect on the design work, the processes used and decisions made.

Table 10 (continued)

Round 2 (Sec2-QA) Practice 6 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DESIGING engineering SOLUTIONS*** all K-12 pre-service teachers must be able to:
A-22	create engineering models.
A-23	define the meaning of "engineering by design".
A-24	define science content in engineering problems.
A-25	understand technology is about modifying the natural world to meet human needs and wants and engineering applies math and science to create technology.
A-26	demonstrate aesthetic quality in engineering solutions.
A-27	demonstrate the engineering design process.
A-28	describe the science content in an engineering problem.
A-29	design engineering solutions to a science problem.
A-30	differentiate between scientific inquiry and engineering design.
A-31	engage in reflection.
A-32	explain design-based engineering practices.
A-33	explain the science content behind an engineering problem.
A-34	understand idea-generating strategies.
A-35	identify alternative engineering solutions.
A-36	identify alternative uses of engineering materials.
A-37	identify connections between science and engineering.
A-38	identify technological/engineering design constraints.

Table 10 (continued)

Round 2 (Sec2-QA) Practice 6 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DESIGING engineering SOLUTIONS*** all K-12 pre-service teachers must be able to:
A-39	identify technological/engineering design criteria.
A-40	identify the engineering design cycle.
A-41	identify grade and age appropriate engineering content.
A-42	identify multiple solutions to solve an engineering problem.
A-43	identify multiple strategies to solve an engineering problem.
A-44	identify the parameters to solve an engineering problem.
A-45	identify resources to solve an engineering problem.
A-46	identify values to solve an engineering problem.
A-47	implement design based engineering instructional methods.
A-48	implement design based engineering instructional strategies.
A-49	implement inquiry-based science pedagogies.
A-50	implement STEM learning experiences regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.
A-51	implement state standards regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.
A-52	incorporate alternative materials to solve engineering problems.
A-53	incorporate alternative techniques to solve engineering problems.
A-54	make informed decisions to solve engineering problems.
A-55	manage student behaviors.

Table 10 (continued)

Round 2 (Sec2-QA) Practice 6 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DESIGING engineering SOLUTIONS*** all K-12 pre-service teachers must be able to:
A-56	meet institutional goals of sustainability.
A-57	model a variety of analytical engineering skills.
A-58	model collaborative brainstorming skills.
A-59	model a variety of physical engineering skills.
A-60	model a variety of virtual engineering skills.
A-61	understand the practice of the engineering design process.
A-62	rearrange the elements of an engineering problem.
A-63	reflect on engineering design solutions.
A-64	sketch and complete finished technical drawings.
A-65	support interdisciplinary collaborations.
A-66	take risks when designing a solution.
A-67	test engineering materials.
A-68	understand the approaches to problem solving found in the Standards for Technology Literacy.
A-69	understand the Disciplinary Core Ideas found in NGSS.
A-70	understand engineering as a process to design a solution.
A-71	understand the engineering design process.
A-72	understand engineering design in relation to understanding science.

Table 10 (continued)

Round 2 (Sec2-QA) Practice 6 Competency Statements

Question #	Round 2 Competency Statements
	To demonstrate competency in ***DESIGING engineering SOLUTIONS*** all K-12 pre-service teachers must be able to:
A-73	understand engineering related problems.
A-74	understand technical writing.
A-75	understand technical components of STEM.
A-76	understand engineering components of STEM.
A-77	understand the utilization of engineering materials.
A-78	understand the vocation of engineering.
A-79	understand the use of models in *NGSS* and how engineering design models differ from models in science.
A-80	complete computer aided design drawings of proposed solutions.
A-81	utilize engineering design to integrate STEM.
A-82	utilize models to design solutions to engineering tasks.
A-83	create a classroom culture that supports collaboration and appreciates that designs should be tested to the point of failure.
A-84	utilize graphical communications.
A-85	utilize modeling.
A-86	utilize real world engineering examples.
A-87	utilize systems thinking.
A-88	safely utilize technological/ engineering tools, machines and instruments.
A-89	value failures.

Question B: Strategy

Round 1 theme analysis. Question B (Sec2-QB) asked the participants to respond to the following guiding question:

> Question B: What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DESIGNING engineering SOLUTIONS*** (strategies used to prepare them to teach that practice)?

The theme analysis for this question resulted 75 instructional strategies (Table 11), accounting for about 18% of the 428 total items on the Round 2 Questionnaire.

Table 11

Round 2 (Sec2-QB) Practice 6 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DESIGN engineering SOLUTIONS*** teacher educators should engage their students in:
B-1	applying engineering problems and processes to specific science content.
B-2	authentic engineering problem solving activities.
B-3	brainstorming ideas for engineering solutions.
B-4	building arguments from evidence.
B-5	building technical devices.
B-6	Capstone projects.
B-7	collaborative brainstorming activities.
B-8	Computer Aided Design.
B-9	concurrent engineering activities.
B-10	coping with K-12 student failure.
B-11	courses with breadth and depth in science concepts.
B-12	dealing with K-12 student resistance when there is not a clear path.

Table 11

Round 2 (Sec2-QB) Practice 6 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DESIGN engineering SOLUTIONS*** teacher educators should engage their students in:
B-13	demonstrating the utilization of science materials
B-14	demonstrations.

Table 11 (countinued)

Round 2 (Sec2-QB) Practice 6 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DESIGN engineering SOLUTIONS*** teacher educators should engage their students in:
B-15	demonstrating a structured process for designing engineering solutions.
B-16	describing the basic steps of engineering design process.
B-17	design teams.
B-18	lesson planning.
B-19	developing knowledge of general technical skills.
B-20	developing possible engineering solutions.
B-21	differentiating invention and innovation.
B-22	discussing the concepts of the NGSS and the integration of subjects as well as how the engineering design practices should be embedded within the curriculum.
B-23	documenting engineering design work.
B-24	engineering activities that requiring debugging.
B-25	the engineering design process.
B-26	instruction in the methodology of problem-solving and how it is applied to engineering practices.
B-27	envisioning solutions through the use of sketching, orthographic projection, perspective drawing, CAD drawing, etc.
B-28	evaluating the strengths and weaknesses of an exemplar science and engineering lesson.
B-29	experiencing cooperative learning strategies.
B-30	experiencing hands-on engineering design activities in their own content area.
B-31	experiencing problems that require an engineering-type solution.
B-32	exposure to multiple engineering design methods.
B-33	facilitated lessons.
B-34	group facilitation.
B-35	hands-on engineering design activities.
B-36	hands-on engineering problem solving activities.
B-37	identifying areas of a lesson that can be enriched with engineering design.

Table 11 (countinued)

Round 2 (Sec2-QB) Practice 6 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DESIGN engineering SOLUTIONS*** teacher educators should engage their students in:
B-38	identifying areas of a lesson that can be enriched with STEM connections
B-39	identifying problems experienced by K-12 science students.
B-40	identifying steps of the engineering design process during reflection.
B-41	identifying the strengths and weaknesses of exemplar science and engineering lessons.
B-42	identifying the vocation of engineering.
B-43	incorporating design activities into case study exploration and resolution.
B-44	iterative engineering design activities.
B-45	modeling visualization techniques.
B-46	modeling design based engineering practices.
B-47	modeling safe technology/engineering tool use.
B-48	open-ended, multiple solution problems.
B-49	peer evaluations for the improvement of engineering designs.
B-50	practicing engineering design problems.
B-51	predictive modeling.
B-52	proposing design solutions that consider human and environmental factors.
B-53	reflecting on key scientific concepts identified and conceptual shifts in NGSS.
B-54	representation modeling
B-55	risk taking classroom culture structures.
B-56	age and grade appropriate engineering design activities.
B-57	selecting appropriate technological/engineering resources.
B-58	technical sketching.
B-59	systems thinking.
B-60	technical drawings.

Table 11 (countinued)

Round 2 (Sec2-QB) Practice 6 Instructional Strategy Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***DESIGN engineering SOLUTIONS*** teacher educators should engage their students in:
B-61	technical writing.
B-62	testing of engineering design solutions.
B-63	technology/engineering tool use.
B-64	trial and error activities of design production and implementation.
B-65	utilizing appropriate technical/engineering resources.
B-66	collect data based on their solutions to the problem.
B-67	utilizing engineering design to integrate multiple content areas into science.
B-68	utilizing scientific evidence to evaluate solutions to engineering problems.
B-69	utilizing cooperative learning activities so students can see how teams are vital to the success of an engineering project.
B-70	utilizing media presentations to show examples of collaborative work skills in engineering design as well as to present their findings.
B-71	utilizing mini lectures on engineering design concepts.
B-72	utilizing concept mapping.
B-73	utilizing formative assessment for engineering design.
B-74	utilizing peer sharing.
B-75	writing lessons for engineering applications of science content.

Instructional Strategies: Section 3 Results

The intent of including the engineering practices of defining problems and designing solutions in the *NGSS* is not to teach students engineering or engineering design, rather the goal is to use design-based engineering practices to engage students in activities that will enhance their understanding and application of science (*NGSS* Lead States, 2013b, p. 3). Thus, the final section of the Round 1 Questionnaire related specifically to instructional strategies.

Instructional Strategies Question

Round 1 theme analysis. The question in section 3 (Sec3–Q Strategy) asked the participants to respond to the following question:

> Question Strategy: What instructional strategies should teacher educators use when preparing K-12 pre-service science teachers to ***intentionally teach targeted science content*** through engineering practices to (strategies used to prepare them to intentional teach science content through that practice)?

The theme analysis for this question resulted in 82 instructional strategy (Table 12) statements, accounting for about 19% of the 428 total items on the Round 2 Questionnaire.

Table 12

Round 2 (Sec3-Q Strategy) Instructional Strategies Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to ***INTENTIONALLY TEACH TARGETED SCIENCE CONTENT*** teacher educators should engage their students in:
S-1	analyzing the appropriateness of an engineering design activity.
S-2	analyzing the effectiveness of an engineering design activity.
S-3	applying engineering practices to a problem clearly linked to science content.
S-4	approaching engineering as a way of doing.
S-5	approaching engineering as a way of thinking.
S-6	authentic science problem solving activities.
S-7	the *NGSS* to identify how the design process can be used to teach specific content by combining different standards and benchmarks.

Table 12 (continued)

Round 2 (Sec3–Q Strategy) Intentional Teaching Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to INTENTIONALLY TEACH TARGETED SCIENCE CONTENT teacher educators should engage their students in:
S-8	content knowledge identified in the NGSS.
S-9	contrasting processes used by scientists with those used by professionals in other disciplines.
S-10	cooperative learning.
S-11	creating tools and instrumentation for collecting scientific data.
S-12	critiquing engineering lessons to identify science content.
S-13	critiquing science lessons to identify engineering content.
S-14	experiencing exemplary engineering design activities.
S-15	designing engineering solutions.
S-16	designing investigative science solutions.
S-17	designing science lesson plans, teaching and then reflecting on these lessons.
S-18	determining engineering problems.
S-19	determining science questions.
S-20	developing age and grade appropriate engineering design challenges.
S-21	developing situational awareness of malfunctioning systems in operation to determine what is not working correctly.
S-22	developing standards-based engineering activities.
S-23	developing standards-based engineering experiences.
S-24	discussing STEM concepts associated with the activity or experience.
S-25	distinguishing between engineering and science concepts.
S-26	establishing collaboration between science teacher educators and technology and engineering teacher educators.
S-27	examining the engineering design process as a content method.
S-28	examining the engineering design process as a pedagogically method.
S-29	exhibiting techniques for questioning different phenomena.

Table 12 (continued)

Round 2 (Sec3–Q Strategy) Intentional Teaching Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to INTENTIONALLY TEACH TARGETED SCIENCE CONTENT teacher educators should engage their students in:
S-30	exposing student teachers to scientific phenomena.
S-31	focusing on a limited number of engineering concepts.
S-32	focusing on broad themes rather than atomistic competencies.
S-33	formative assessment of open ended engineering problems.
S-34	framing engineering design activities as a tool for getting to the science content objectives of the *NGSS* standard we're addressing.
S-35	hands on/minds on science activities.
S-36	identifying engineering situations that enable the integration of science lessons.
S-37	identifying and discuss cross-disciplinary intersections between science, technology, and engineering education.
S-38	identifying educational objectives.
S-39	the process of identifying key science content.
S-40	identifying STEM concepts associated with the activity or experience.
S-41	implementing age and grade appropriate engineering design challenges.
S-42	inquiry based activities.
S-43	scientific inquiry instruction.
S-44	the use of science rubrics such as the dimensions of success tool to measure student engagement.
S-45	introducing students to technology and engineering organizations such as ITEEA & ASEE.
S-46	introducing targeted science content through guided practice.
S-47	iterative engineering design activities.
S-48	judge spatial relationships, (e.g., visualize how a system operates and mentally rotate system parts to solve problems within a given system.)
S-49	lessons and activities where students are faced with an engineering problem.
S-50	lessons where science content is taught through engineering practices.

Table 12 (continued)

Round 2 (Sec3–Q Strategy) Intentional Teaching Statements

Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to INTENTIONALLY TEACH TARGETED SCIENCE CONTENT teacher educators should engage their students in:
S-51	making comparisons, (e.g., what commonalities and differences do systems have?)
S-52	making predictions, (e.g., based on what has been observed, what is known about a specific system, and what is known about related scientific principles, make a prediction about what will happen next.)
S-53	managing group-oriented projects.
S-54	managing open-ended, multiple solution problems.
S-55	short video clips or actual teaching sequences to illustrate how a master teacher uses the design activity to teach targeted science content.
S-56	modeling integrating science teaching in engineering design.
S-57	participating in science lessons as K-12 students.
S-58	problem based learning activities.
S-59	providing engineering is elementary and other curriculum resources.
S-60	providing resources such as websites, handouts, expert guest speakers, etc.
S-61	recognizing probable outcomes, (e.g., how will the system react to a specific action?)
S-62	the same things used to teach technology and engineering teachers.
S-63	science-specific pedagogical approaches.
S-64	scientific argumentation.
S-65	summative assessments.
S-66	teaching sequences utilizing design activities.
S-67	technological problem solving techniques.
S-68	understanding cause and effect relationships.
S-69	understanding how engineering and science concepts function.
S-70	understanding inquiry.
S-71	understanding science concepts.

Table 12 (continued)

Round 2 (Sec3–Q Strategy) Intentional Teaching Statements

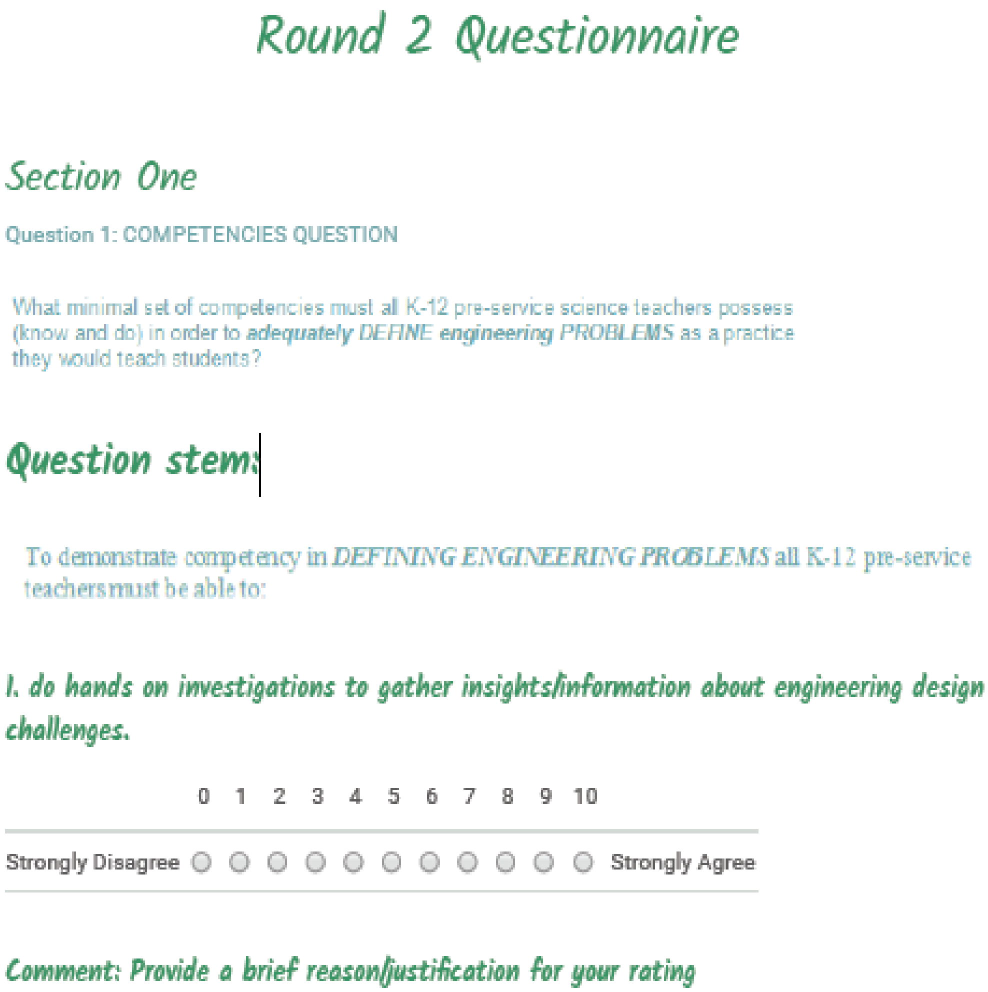
Question #	Round 2 Instructional Strategy Statements
	When preparing K-12 pre-service teachers to INTENTIONALLY TEACH TARGETED SCIENCE CONTENT teacher educators should engage their students in:
S-72	understanding STEM content learning.
S-73	understanding STEM engagement.
S-74	understanding the concepts of engineering design as in described in the NGSS.
S-75	utilizing continuous assessment.
S-76	utilizing professional journals to explore teaching pedagogies
S-77	utilizing science to solve engineering problems.
S-78	utilizing STEM to solve social problems.
S-79	utilizing the engineering design process in solving an engineering/technology problem.
S-80	utilizing the pedagogical approach of modeling science curriculum.
S-81	utilizing the pedagogical approach of scientific inquiry.
S-82	utilizing the scientific method in solving a engineering/technology problem.

Rounds 2 and 3 Data Analysis

This section presents the analysis of data from Rounds 2 and 3 of this Delphi Study. The design of the Rounds 2 and 3 Questionnaires followed the same section and question format as Round 1 (see Table 4 for a complete listing of all sections). However, Rounds 2 and 3 differed from Round 1in terms of the type of data collection and subsequent analysis.

The Round 1 Questionnaire was designed to collect data in the form of open-ended responses. For Round 2, these responses were consolidated in to statements that panelists were asked to rate using an 11-point Likert scale. These scales were used to collect data to measure the level of agreement among panel members on the importance of given statements identified from

Round 1. In addition to rating each of these statements, panel members were asked to provide comments/justifications for their rating. In future rounds panelists were asked to review other panel members' comments/justifications and invited to re-rate or confirm each of their responses based on these data. In order to order to move the panel closer to consensus, each panelist was provided with the mode and comments/justifications for each question. This served as a mechanism for passively persuading panelist to change their rating for a given competency. An example of the question format of the Round 2 and 3 Questionnaires are shown below in Figures 4 and 5. Both the Round 2 and 3 Questionnaires were created and administered through the use of Google forms. Based on panelists' suggestions, changes in graphical presentation were made between Rounds 2 and 3 in increase readability. Please see Appendices H and I for more complete examples of how these questionnaires were presented to the panelists.



Round 2 Questionnaire

Section One

Question 1: COMPETENCIES QUESTION

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Question stem:

To demonstrate competency in ***DEFINING ENGINEERING PROBLEMS*** all K-12 pre-service teachers must be able to:

I. do hands on investigations to gather insights/information about engineering design challenges.

	0	1	2	3	4	5	6	7	8	9	10	
Strongly Disagree	○	○	○	○	○	○	○	○	○	○	○	Strongly Agree

Comment: Provide a brief reason/justification for your rating

Figure 4: Sample question from Round 2 Section 1 Question 1A.

Section One: COMPETENCIES QUESTION

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Response A-2: Explain engineering problems.

The Modal rating for this item is: 10

The most commonly chosen rating/ratings are highlighted in yellow.

Strongly Disagree										Strongly Agree
0	1	2	3	4	5	6	7	8	9	10
1	1	0	1	0	0	0	1	2	1	[illegible]

Your Original Rating is 1 and the blue arrow represents your position among the panelists for this item.

Panel Member Comments: rate your response either the same or differently based on other panelists comments listed below.

Explaining the problem does not require hands on investigation. Teachers can learn to explain design problems through research, discussion, graphic, and written means.

Students must be provided with the 'attack skills' necessary to understand the process of problem solving as it relates to the design process.

It is important to be able to articulate and clarify the nature of engineering problems.

Not sure what this means—are students explaining how to do a problem or explaining what a problem might look like?

I don't know what it means to "explain engineering problems." Is it different than "define engineering problems"? If it isn't, then the I strongly agree that for K-12 teachers to adequately define engineering problems they should be able to define engineering problems.

Should be able to discuss how engineering problems are open-ended.

They need to know what an engineering problem is.

I am not sure I would describe the problem as an engineering problem.

Re-Rating Your Response to A2:

Based on other panelists' comments listed above, re-rate your response either the same or differently.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ Strongly Agree

Comment:

Provide a brief reason/justification why you kept your original rating or chose to change.

Figure 5: Sample question from Round 3 Section 1 Question 2A.

Round 2 data analysis began with determining the median and mode for each panelist's Likert scale rating of an item, as well as the interquartile range (IQR) for their collective responses. As discussed in detail in the methods section of this document, statements with an IQR greater than 4.0 indicated disagreement among the panel. In Round 3, panel members were asked to reconsider their ratings of these statements.

To determine if an item was to be included in the final framework, the group median of each item was calculated. Each panelists rating was then compared to this median. A median at or above 7.50 indicated the panelists believed this item was important and should be included in the framework. Calculation of IQR was then used to determine if there was consensus among the panelists regarding the rating of that item. Items with a median score at or greater than 7.50 and an IQR at or less than 4.0 indicated that the panelists agreed the item "should be" included in the framework. Items with less than a median of 7.5 and an IQR greater than 4.0 indicated panelists agree the item "should not" be included in the framework. All other items (i.e., IQR > 4) were carried forward to Round 3. Provided below in Figure 6 are the three scenarios for panelists judgment of a Round 2 item.

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">IQR</td></tr>
<tr><td>≤ 4.0</td><td>> 4.0</td></tr>
<tr><td rowspan="2">Median</td><td>≥ 7.50</td><td>Accepted: competencies which panelists agree should be included in a future framework</td><td rowspan="2">Non-consensus: competencies carried over to Round 3</td></tr>
<tr><td>< 7.50</td><td>Rejected: competencies which panelists agreed should not be considered in a future framework</td></tr>
</table>

Figure 6: Accepted, rejected and non-consensus calculations.

All items not meeting consensus in Round 2 were re-presented on the Round 3 Questionnaire along with the group mode, individual position relative to the mode, and comments from all panelists' on each item. In Round 3 panelists were asked to review each statement along with the comments/ justifications of the other panel members. They were then asked based on this data provided if they would like to re-rank their response. Data analysis for Round 3 followed the same protocol as detailed above for Round 2. Stability was reached for all statements during the third round, as no item's median changed by more than 15% between Rounds 2 and 3. This indicator of stability was discussed in the methods section of this study.

Practice 1 - Defining Engineering Problems: Section 1 Results

Presented below are the results of data analysis for Rounds 2 and 3. The next segment of this analysis begins by explaining in detail how Section 1 Question A (Sec1-QA) data was analyzed. This same method of analysis is applied for each of the remaining sections. With the exception of Sec1-QA only the accepted items are presented in this chapter; complete listings of non-consensus and rejected items are contained in Appendix K and L respectively.

Question A: Competency

Round 2 data analysis. The statements listed on the Round 2 Questionnaire are directly derived from the results of the Round 1 theme analysis. During Round 1, Sec1-QA asked panelists respond to the following question:

> <u>Question A:</u> What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

The Round 1 Section1 theme analysis identified a total of 80 Sec1-QA competencies (Table 8). The results of Round 2 data analysis for Sec1-QA found that the panel reached agreement on 61 of the 80 (76.3%) suggested competencies. There was agreement that 47 (58.8%) should be considered as a competency all K-12 pre-service science teachers must possess and 14 (17.5%) (Appendix K) of the 80 Sec1-QA competencies “should not” be included in the framework. Results of data analysis from Round 2 also found that 19 (23.8%) of the 80 Sec1-QA competences did not reach consensus (Appendix L). These competences were classified as non-consensus competences and were advanced forward to the third round.

Round 3 data analysis. The results of data analysis from the Round 2 Questionnaire identified a total of 19 Sec1-QA non-consensus competencies. During Round 3, panelists agreed on inclusion of six additional Sec1-QA *NGSS* Practice 1 Competencies. These items were determined by median and IQR for each of the items on the Round 3 Questionnaire. As determined from Rounds 2 and 3, the resulting 53 Practice 1 Competencies (66.3% of the original 80) panelists agreed that all pre-service science teachers must possess are displayed in Table 13.

Table 13

Round 2 & 3 (Sec1-QA) 53 Accepted Practice 1 Competencies

Question #	Competencies	Median	IQR
A-59	provide meaningful examples of engineering and engineering problems that will be understood by their students.	10.0	1.00
A-16	define a engineering problem.	10.0	1.75
A-57	identify engineering problems.	10.0	2.00

Table 13

Round 2 & 3 (Sec1-QA) 53 Accepted Practice 1 Competencies

Question #	Competencies	Median	IQR
A-26	develop solutions to engineering problems.	10.0	2.75
A-70	understand engineering problems.	10.0	2.75
A-54	model the engineering process to demonstrate that this process differs from the scientific process.	10.0	3.00

Table 13 (continued)

Round 2 & 3 (Sec1-QA) 53 Accepted Practice 1 Competencies

Question #	Competencies	Median	IQR
A-2	explain engineering problems.	10.0	3.00
A-22	describe the basic steps of the engineering design process.	10.0	3.50
A-60	select grade and age appropriate engineering design scenarios and challenges that enable the application of scientific concepts.	9.5	2.00
A-66	understand the design constraints of an engineering problem.	9.5	2.00
A-19	demonstrate that technology is about modifying the natural world to meet human needs and wants.	9.5	2.00
A-36	identify the constraints on an engineering problem.	9.5	2.75
A-65	identify the desired performances, criteria and constraints of an engineering design challenge.	9.0	2.00
A-37	identify engineering design criteria.	9.0	2.00
A-15	define the constraints of engineering problems.	9.0	2.00
A-67	understand the design tradeoffs of an engineering problem.	9.0	2.00
A-31	explain what engineering is.	9.0	2.00
A-79	utilize real world examples when solving engineering design problems.	9.0	2.00
A-32	facilitate student development in engineering design practices.	9.0	2.50
A-41	identify grade and age appropriate engineering content.	9.0	2.75
A-6	ask questions about engineering problems.	9.0	2.75

Table 13 (continued)

Round 2 & 3 (Sec1-QA) 53 Accepted Practice 1 Competencies

Question #	Competencies	Median	IQR
A-30	explain the meaning of engineering.	9.0	2.75
A-29	explain how the engineering process differs from the scientific method.	9.0	3.00
A-21	define what engineering is.	9.0	3.00
A-72	understand how to teach engineering practices.	9.0	3.00
A-20	define the meaning of engineering.	9.0	3.75
A-51	implement technology and engineering instructional strategies.	9.0	4.00
A-28	embed engineering activities into science content.	9.0	4.00
A-62	use the engineering design process to solve a problem.	9.0	4.00
A-42	identify interdisciplinary connections to engineering.	8.5	3.00
A-4	research solutions to an engineering problem.	8.5	3.00
A-47	implement design based strategies in technology and engineering and STEM focused curricular applications.	8.5	3.50
A-5	explain engineering design problems in written form.	8.5	3.50
A-27	differentiate between the practices of scientific inquiry and engineering design.	8.5	3.75
A-35	identify the concepts that occur in economics, engineering, human impact, safety, and technology and how they related to technology and engineering education.	8.5	3.75
A-64	understand the concepts of grade and age appropriate engineering activities.	8.0	2.00

Table 13 (continued)

Round 2 & 3 (Sec1-QA) 53 Accepted Practice 1 Competencies

Question #	Competencies	Median	IQR
A-77	utilize educational standards in the development of engineering problems.	8.0	2.00
A-39	identify the critical content and skills objectives of an educational standard in order to intentionally focus the development of engineering problems during a lesson.	8.0	3.00
A-61	define a problem that can be solved using technical means.	8.0	3.00
A-9	demonstrate logical thinking when planning engineering tasks.	8.0	3.00
A-12	break engineering problems into smaller parts.	8.0	3.50
A-38	identify engineering design performances.	8.0	3.50
A-33	focus on practical engineering solutions to a problem.	8.0	3.75
A-8	apply Disciplinary Core Ideas	8.0	4.00
A-80	utilize engineering tools and instruments.	8.0	4.00
A-48	implement design based instructional methods in technology and engineering and STEM focused curricular applications.	8.0	4.00
A-56	analyze engineering problems.	8.0	4.00
A-69	understand engineering as a process.	8.0	4.00
A-3	identify multiple solutions to an engineering problem.	7.5	2.50
A-43	identify how personal beliefs influence design.	7.5	2.75
A-44	identify other practices of academia, such as economics, human impact, and safety, and relate them to practices of engineering and science.	7.5	3.75
A-46	identify the technology and engineering practices in each of the STEM fields.	7.5	3.75
A-50	implement technology and engineering instructional methods.	7.5	3.75

The following segments of this chapter will present summaries of data analysis for Rounds 2 and 3 for section 2 and section 3. Specifically, only the accepted statements for Rounds 2 and 3 are presented collectively. See Appendix K for a complete listing of the Round 2 and 3 rejected statements. For a listing of stable Round 3 non-consensus rejected statements items see Appendix M.

Question B: Instructional Strategy

Round 2 data analysis. The statements listed on the Round 2 Questionnaire are directly derived from the results of the Round 1 theme analysis. During Round 1, Sec1-QB asked panelists respond to the following question:

> Question B: What instructional strategy/strategies should teacher educator's use when preparing K-12 pre-service science teachers to teach students ***the practice of DEFINING engineering PROBLEMS*** (strategies used to prepare them to teach that practice)?

The Round 1 Section1 theme analysis identified a total of 102 Sec1- QB instructional strategies (Table 9). The results of Round 2 data analysis for Sec1- QB found that the panel reached agreement on 76 of the 102 (74.5 %) suggested instructional strategies. There was agreement that 52 (51%) should be considered as an instructional strategy used to prepare K-12 pre-service science teachers and 24 (23.5%) (Appendix K) of the 102 Sec1-QB instructional strategies "should not" be included in the framework. Results of data analysis from Round 2 also found that 26 (25.5%) of the 102 Sec1-QB instructional strategies did not reach consensus (L). These instructional strategies were classified as non-consensus instructional strategies and were advanced forward to the third round.

Round 3 data analysis. The results of data analysis from the Round 2 Questionnaire identified a total of 26 Sec1-QB non-consensus instructional strategies. During Round 3, panelists agreed on inclusion of seven additional Sec1-QB *NGSS* Practice 1 Instructional Strategies. These items were determined by median and IQR for each of the items on the Round 3 Questionnaire. As determined from Rounds 2 and 3, the resulting 59 Practice 1 Instructional Strategies (57.8% of the original 102) panelists agreed that all pre-service science teachers must possess are displayed in Table 14.

Table 14

Round 2 & 3 (Sec1-QB) 59 Accepted Practice 1Instructional Strategies

Question #	Instructional Strategies	Median	IQR
B-20	defining engineering problems.	10.0	1.00
B-29	designing hands-on problem solving lessons in science and engineering.	10.0	1.25
B-46	identifying the technological/engineering constraints of engineering problem.	10.0	2.00
B-71	problem based engineering activities.	10.0	2.00
B-48	identifying technological/engineering problems.	10.0	2.50
B-50	identifying engineering problems.	10.0	2.50
B-22	demonstrating the difference between scientific inquiry and engineering design.	10.0	3.00
B-4	applying engineering practices.	10.0	3.50
B-47	identifying the technological/engineering criteria of an engineering problem.	10.0	3.50
B-63	modeling safe technology and engineering tool use.	10.0	3.50
B-74	providing feedback to K-12 students.	10.0	3.50

Table 14 (continued)

Round 2 & 3 (Sec1-QB) 59 Accepted Practice 1Instructional Strategies

Question #	Instructional Strategies	Median	IQR
B-44	hands-on engineering design activities.	10.0	3.00
B-64	open-ended, multiple solution engineering problems.	9.5	2.00
B-82	appropriate instructional strategies to engage students in the engineering design-processes.	9.5	2.25
B-91	using instructional strategies to monitor student progress of engineering design concepts.	9.5	2.50
B-13	collaborative engineering learning activities.	9.5	2.75
B-3	developing problem-based learning activities and lessons that require students to apply engineering concepts.	9.0	1.00
B-88	using formative assessments to gather evidence of students' learning, provide timely feedback, and adjust daily instruction.	9.0	1.75
B-35	development of engineering design challenges.	9.0	2.50
B-12	collaborative engineering design activities.	9.0	2.75
B-49	identifying design constraints due to available materials or class time.	9.0	3.00
B-32	developing knowledge of technical skills.	9.0	3.25
B-92	using integrative engineering design based instructional strategies.	9.0	3.25
B-73	developing engineering prototypes.	9.0	3.50
B-93	using performance rubrics to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.	9.0	3.50
B-36	differentiating between scientific inquiry and engineering design.	9.0	4.00

Table 14 (continued)

Round 2 & 3 (Sec1-QB) 59 Accepted Practice 1Instructional Strategies

Question #	Instructional Strategies	Median	IQR
B-67	practicing project based engineering learning challenges.	9.0	4.00
B-7	creating authentic engineering activities.	8.5	2.25
B-72	design based engineering instruction.	8.5	2.25
B-97	utilizing engineering design exemplars.	8.5	2.25
B-15	comparing and contrasting the science approach to the engineering approach in order to solve the same problem.	8.5	3.00
B-28	designing age and grade appropriate inquiry/design based instructional models.	8.5	3.25
B-80	teaching mini engineering lessons to their peers	8.5	3.25
B-9	brainstorming engineering activities.	8.5	3.25
B-5	developing problem-based learning activities and lessons that require students to apply scientific concepts.	8.5	4.00
B-26	design-based lessons to modeling the practices identified in the NGSS.	8.0	1.50
B-59	making connections between science and engineering practices.	8.0	2.00
B-6	developing problem-based learning activities and lessons that require students to apply scientific practices.	8.0	2.00
B-2	analyzing engineering case studies.	8.0	2.50
B-53	interdisciplinary STEM teams to solve engineering problems.	8.0	2.50
B-81	applying technological/engineering design pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education.	8.0	2.50

Table 14 (continued)

Round 2 & 3 (Sec1-QB) 59 Accepted Practice 1Instructional Strategies

Question #	Instructional Strategies	Median	IQR
B-42	documenting engineering design solutions.	8.0	3.00
B-78	reviewing engineering case studies.	8.0	3.00
B-94	using summative assessments to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.	8.0	3.00
B-34	developing problem-based learning activities that requires students to apply both scientific and engineering concepts and practices.	8.0	3.25
B-43	embracing ambiguity and guiding students towards a understanding of a problem.	8.0	3.25
B-1	administering problem-based engineering activities.	8.0	3.50
B-23	demonstrations of laboratory practices used in technology and engineering.	8.0	3.50
B56	keeping a journal.	8.0	3.50
B-76	reflecting on the environmental safety, economical, and human impact constraints of a science problem.	8.0	3.50
B-90	using hands on learning experiences in students own discipline (bio, Chemistry, physics).	8.0	3.50
B-98	media presentations of exemplary science and engineering instruction.	8.0	3.50
B-33	developing technological problem statements.	8.0	4.00
B-45	hands-on problem solving activities.	8.0	4.00
B-17	conducting curriculum inventories to identify potential areas to utilize engineering design.	7.5	2.75
B-14	collaboratively aligning science and engineering lessons to the NGSS.	7.5	3.25
B-39	discussing concepts of the NGSS and how engineering design practices should be embedded within the curriculum.	7.5	3.25
B-10	designing and building a technical device that solves an engineering problem.	7.5	4.00

Table 14 (continued)

Round 2 & 3 (Sec1-QB) 59 Accepted Practice 1Instructional Strategies

Question #	Instructional Strategies	Median	IQR
B-31	determining to involve engineering design in science problems.	7.5	4.00

Section 2 Results: Practice 6 - Designing Engineering Solutions

The purpose of the two questions in Section 2 of the Round 2 and 3 Questionnaire was to present all the combined statements identified by the panel during Round 1and encourage consensus as to which competencies all K-12 pre-service science teachers should possess in order to design engineering solutions and the strategies teacher educators should use when preparing them to teach this practice.

Question A: Competency

Round 2 data analysis. The statements listed on the Round 2 Questionnaire are directly derived from the results of the Round 1 theme analysis. During Round 1, Sec2-QA asked panelists respond to the following question:

Question A: What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DESIGN engineering SOLUTIONS*** as a practice they would teach students?

The Round 1 Section 2 theme analysis identified a total of 89 Sec2-QA competencies (Table 10). The results of Round 2 data analysis for Sec2-QA found that the panel reached agreement on 71 of the 89 (79.8%) suggested competencies. There was agreement that 61 (68.6%) should be considered as a competency all K-12 pre-service science teachers must possess and 10 (11.2%) (Appendix K) of the 89 Sec2-QA competencies “should not” be included in the framework.

Results of data analysis from Round 2 also found that 18 (20.2%) of the 89 Sec2-QA competences did not reach consensus (Appendix L). These competences were classified as non-consensus competences and were advanced forward to the third round.

Round 3 data analysis. The results of data analysis from the Round 2 Questionnaire identified a total of 18 Sec2-QA non-consensus competencies. During Round 3, panelists agreed on inclusion of seven additional Sec2-QA *NGSS* Practice 6 Competencies. These items were determined by median and IQR for each of the items on the Round 3 Questionnaire. As determined from Rounds 2 and 3, the resulting 68 Practice 6 Competencies (76.4% of the original 89) panelists agreed that all pre-service science teachers must possess are displayed in Table 15.

Table 15

Round 2 & 3 (Sec2-QA) 68 Accepted Practice 6 Competencies

Question #	Competencies	Median	IQR
A-55	manage student behaviors.	10.0	1.00
A-88	safely utilize technological/ engineering tools, machines and instruments.	10.0	1.00
A-4	choose an engineering design solution.	10.0	1.25
A-41	identify grade and age appropriate engineering content.	10.0	1.25
A-61	understand the practice of the engineering design process.	10.0	1.25
A-71	understand the engineering design process.	10.0	1.25
A-27	demonstrate the engineering design process.	10.0	2.00
A-38	identify technological/engineering design constraints.	10.0	2.00
A-39	identify technological/engineering design criteria.	10.0	2.00

Table 15

Round 2 & 3 (Sec2-QA) 68 Accepted Practice 6 Competencies

Question #	Competencies	Median	IQR
A-31	engage in reflection.	10.0	3.00
A-7	design and test engineering prototypes.	10.0	3.00

Table 15 (continued)

Round 2 & 3 (Sec2-QA) 68 Accepted Practice 6 Competencies

Question #	Competencies	Median	IQR
A-25	understand technology is about modifying the natural world to meet human needs and wants and engineering applies math and science to create technology.	10.0	3.50
A-70	understand engineering as a process to design a solution.	9.5	1.75
A-22	create engineering models.	9.5	2.00
A-42	identify multiple solutions to solve an engineering problem.	9.5	2.25
A-48	implement design based engineering instructional strategies.	9.5	2.25
A-5	do hands on engineering prototyping activities.	9.5	2.25
A-6	identify multiple solutions to an engineering problem.	9.5	2.25
A-87	utilize systems thinking.	9.5	3.00
A-40	identify the engineering design cycle.	9.5	4.00
A-72	understand engineering design in relation to understanding science.	9.0	2.00
A-2	analyze engineering design solutions.	9.0	2.25
A-45	identify resources to solve an engineering problem.	9.0	2.25
A-63	reflect on engineering design solutions.	9.0	2.25
A-81	utilize engineering design to integrate STEM.	9.0	2.25
A-82	utilize models to design solutions to engineering tasks.	9.0	2.25

Table 15 (continued)

Round 2 & 3 (Sec2-QA) 68 Accepted Practice 6 Competencies

Question #	Competencies	Median	IQR
A-37	identify connections between science and engineering.	9.0	2.50
A-21	share engineering design ideas and solutions to reflect on the design work, the processes used and decisions made.	9.0	3.00
A-47	implement design based engineering instructional methods.	9.0	3.00
A-58	model collaborative brainstorming skills.	9.0	3.00
A-65	support interdisciplinary collaborations.	9.0	3.00
A-86	utilize real world engineering examples.	9.0	3.00
A-89	value failures.	9.0	3.00
A-32	explain design-based engineering practices.	9.0	3.25
A-68	understand the approaches to problem solving found in the Standards for Technology Literacy.	9.0	4.00
A-43	identify multiple strategies to solve an engineering problem.	8.5	2.25
A-66	take risks when designing a solution.	8.5	2.25
A-9	utilize feedback to refine engineering prototypes.	8.5	2.25
A-85	utilize modeling.	8.5	2.50
A-16	demonstrate logical thinking in the design of engineering activities.	8.5	3.00
A-51	implement state standards regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.	8.5	3.00

Table 15 (continued)

Round 2 & 3 (Sec2-QA) 68 Accepted Practice 6 Competencies

Question #	Competencies	Median	IQR
A-35	identify alternative engineering solutions.	8.5	3.25
A-69	understand the Disciplinary Core Ideas found in NGSS.	8.5	3.25
A-64	sketch and complete finished technical drawings.	8.5	3.50
A-13	analyze STEM learning experiences regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.	8.0	2.00
A-53	incorporate alternative techniques to solve engineering problems.	8.0	2.50
A-33	explain the science content behind an engineering problem.	8.0	2.75
A-30	differentiate between scientific inquiry and engineering design.	8.0	3.00
A-44	identify the parameters to solve an engineering problem.	8.0	3.00
A-76	understand engineering components of STEM.	8.0	3.00
A-10	adapt prior engineering design solutions.	8.0	3.25
A-15	apply design, engineering and technology literacy standards in the design and implementation of DTE learning activities.	8.0	3.25
A-28	describe the science content in an engineering problem.	8.0	3.25
A-78	understand the vocation of engineering.	8.0	3.25
A-79	understand the use of models in *NGSS* and how engineering design models differ from models in science.	8.0	3.25
A-3	analyze scientific data.	8.0	3.50

Table 15 (continued)

Round 2 & 3 (Sec2-QA) 68 Accepted Practice 6 Competencies

Question #	Competencies	Median	IQR
A-62	rearrange the elements of an engineering problem.	8.0	3.50
A-23	define the meaning of "engineering by design".	8.0	4.00
A-54	make informed decisions to solve engineering problems.	8.0	4.00
A-83	create a classroom culture that supports collaboration and appreciates that designs should be tested to the point of failure.	8.0	4.00
A-84	utilize graphical communications.	8.0	4.00
A-73	understand engineering related problems.	7.5	2.50
A-17	apply STEM pedagogical concepts in design, technology and engineering education in STEM focused curricular models.	7.5	3.00
A-75	understand technical components of STEM.	7.5	3.00
A-67	test engineering materials.	7.5	3.25
A-77	understand the utilization of engineering materials.	7.5	3.50
A-46	identify values to solve an engineering problem.	7.5	3.75
A-50	implement STEM learning experiences regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.	7.5	4.00

Question B: Instructional Strategy

Round 2 data analysis. The statements listed on the Round 2 Questionnaire are directly derived from the results of the Round 1 theme analysis. During Round 1, Sec2-QB asked panelists respond to the following question:

> Question B: What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DESIGNING engineering SOLUTIONS*** (strategies used to prepare them to teach that practice)?

The Round 1 Section 2 theme analysis identified a total of 75 Sec2-QB instructional strategies (Table 11). The results of Round 2 data analysis for Sec2- QB found that the panel reached agreement on 64 of the 75 (85.3 %) suggested instructional strategies. There was agreement that 59 (78.7%) should be considered as an instructional strategy used to prepare K-12 pre-service science teachers and 5 (6.7%) (Appendix K) of the 75 Sec2-QB instructional strategies “should not” be included in the framework. Results of data analysis from Round 2 also found that 11 (14.7%) of the 75 Sec2-QB instructional strategies did not reach consensus (Appendix L). These instructional strategies were classified as non-consensus instructional strategies and were advanced forward to the third round.

Round 3 data analysis. The results of data analysis from the Round 2 Questionnaire identified a total of 11 Sec2-QB non-consensus instructional strategies. During Round 3, panelists agreed on inclusion of three additional Sec2-QB *NGSS* Practice 6 Instructional Strategies. These items were determined by median and IQR for each of the items on the Round 3 Questionnaire. As determined from Rounds 2 and 3, the resulting 62 Practice 1 Instructional

Strategies (82.7% of the original 75) panelists agreed that all pre-service science teachers must possess are displayed in Table 16.

Table 16

Round 2 & 3 (Sec2-QB) 62 Accepted Practice 6 Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
B-36	hands-on engineering problem solving activities.	10.0	0.50
B-18	lesson planning.	10.0	1.00
B-47	modeling safe technology/engineering tool use.	10.0	1.00
B-30	experiencing hands-on engineering design activities in their own content area.	10.0	1.25
B-56	age and grade appropriate engineering design activities.	10.0	1.25
B-35	hands-on engineering design activities.	10.0	1.50
B-31	experiencing problems that require an engineering-type solution.	10.0	2.00
B-50	practicing engineering design problems.	10.0	2.00
B-25	the engineering design process.	10.0	2.50
B-14	demonstrations.	10.0	3.25
B-62	testing of engineering design solutions.	9.5	1.25
B-46	modeling design based engineering practices.	9.5	2.00
B-2	authentic engineering problem solving activities.	9.5	2.25
B-40	identifying steps of the engineering design process during reflection.	9.5	2.25

Table 16 (continued)

Round 2 & 3 (Sec2-QB) 62 Accepted Practice 6 Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
B-15	demonstrating a structured process for designing engineering solutions.	9.5	2.50
B-16	describing the basic steps of engineering design process.	9.5	2.50
B-57	selecting appropriate technological/engineering resources.	9.5	2.50
B-39	identifying problems experienced by K-12 science students.	9.5	2.75
B-59	systems thinking.	9.5	3.25
B-48	open-ended, multiple solution problems.	9.0	1.25
B-19	developing knowledge of general technical skills.	9.0	1.50
B-10	coping with K-12 student failure.	9.0	2.00
B-20	developing possible engineering solutions.	9.0	2.00
B-63	technology/engineering tool use.	9.0	2.00
B-26	instruction in the methodology of problem-solving and how it is applied to engineering practices.	9.0	2.25
B-28	evaluating the strengths and weaknesses of an exemplar science and engineering lesson.	9.0	2.25
B-73	utilizing formative assessment for engineering design.	9.0	2.25
B-51	predictive modeling.	9.0	2.50
B-7	collaborative brainstorming activities.	9.0	2.50

Table 16 (continued)

Round 2 & 3 (Sec2-QB) 62 Accepted Practice 6 Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
B-44	iterative engineering design activities.	9.0	3.00
B-52	proposing design solutions that consider human and environmental factors.	9.0	3.00
B-69	utilizing cooperative learning activities so students can see how teams are vital to the success of an engineering project.	9.0	3.50
B-6	Capstone projects.	9.0	3.75
B-23	documenting engineering design work.	8.5	2.25
B-37	identifying areas of a lesson that can be enriched with engineering design.	8.5	2.25
B-66	collect data based on their solutions to the problem.	8.5	2.25
B-68	utilizing scientific evidence to evaluate solutions to engineering problems.	8.5	2.50
B-27	envisioning solutions through the use of sketching, orthographic projection, perspective drawing, CAD drawing, etc.	8.5	4.00
B-29	experiencing cooperative learning strategies.	8.5	4.00
B-65	utilizing appropriate technical/engineering resources.	8.5	4.00
B-42	identifying the vocation of engineering.	8.0	0.50
B-3	brainstorming ideas for engineering solutions.	8.0	2.00
B-41	identifying the strengths and weaknesses of exemplar science and engineering lessons.	8.0	2.00
B-1	applying engineering problems and processes to specific science content.	8.0	2.25

Table 16 (continued)

Round 2 & 3 (Sec2-QB) 62 Accepted Practice 6 Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
B-12	dealing with K-12 student resistance when there is not a clear path.	8.0	2.25
B-67	utilizing engineering design to integrate multiple content areas into science.	8.0	2.25
B-11	courses with breadth and depth in science concepts.	8.0	2.50
B-22	discussing the concepts of the NGSS and the integration of subjects as well as how the engineering design practices should be embedded within the curriculum.	8.0	2.50
B-32	exposure to multiple engineering design methods.	8.0	3.00
B-33	facilitated lessons.	8.0	3.00
B-49	peer evaluations for the improvement of engineering designs.	8.0	3.00
B-13	demonstrating the utilization of science materials	8.0	3.50
B-17	design teams.	8.0	3.50
B-55	risk taking classroom culture structures.	8.0	3.50
B-71	utilizing mini lectures on engineering design concepts.	8.0	3.50
B-5	building technical devices.	8.0	3.75
B-38	identifying areas of a lesson that can be enriched with STEM connections	8.0	4.00
B-74	utilizing peer sharing.	7.5	2.50
B-21	differentiating invention and innovation.	7.5	3.75

Table 16 (continued)

Round 2 & 3 (Sec2-QB) 62 Accepted Practice 6 Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
B-58	technical sketching.	7.5	4.00
B-61	technical writing.	7.5	4.00
B-64	trial and error activities of design production and implementation.	7.5	4.00

Section 3 Results: Instructional Strategy

Practice 1 and 6 of the *NGSS* necessitates teachers have the ability to implement design-based engineering practices to intentionally teach targeted science content. The Round 1 Questionnaire asked panelists to identify the instructional strategies teacher educators should use when preparing K-12 pre-service science teachers to ***intentionally teach targeted science content*** through engineering practices to (strategies used to prepare them to intentional teach science content through that practice).

Question Strategy: Instructional Strategies

Round 2 data analysis. The statements listed on the Round 2 Questionnaire are directly derived from the results of the Round 1 theme analysis. During Round 1, The Section 3 Instructional Strategy question asked panelists respond to the following question:

> Instructional Strategy Question: What instructional strategies should teacher educators use when preparing K-12 pre-service science teachers ***to intentionally teach targeted science content*** through engineering practices to (strategies used to prepare them to intentional teach science content through that practice)?

The Round 1 Section3 theme analysis identified a total of 82 instructional strategies (Table 12). The results of Round 2 data analysis for Section 3 found that the panel reached agreement on 69 of the 82 (84.1 %) suggested instructional strategies. There was agreement that 64 (78%) should be considered as an instructional strategy used to prepare K-12 pre-service science teachers and 5 (6.1%) (Appendix K) of the 82 instructional strategies “should not” be included in the framework. Results of data analysis from Round 2 also found that 13 (15.9%) of the 82 instructional strategies did not reach consensus (Appendix L). These instructional strategies were classified as non-consensus instructional strategies and were advanced forward to the third round.

Round 3 data analysis. The results of data analysis from the Round 2 Questionnaire identified a total of 13 non-consensus instructional strategies. During Round 3, panelists agreed on inclusion of seven additional instructional strategies. These items were determined by median and IQR for each of the items on the Round 3 Questionnaire. As determined from Rounds 2 and 3, the resulting 71 instructional strategies (86.6% of the original 82) panelists agreed that all pre-service science teachers must possess are displayed in Table 17.

Table 17

Round 2 & 3 (Sec3-Q Strategy) 71 Accepted Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
S-79	utilizing the engineering design process in solving an engineering/technology problem.	10.0	1.25
S-75	utilizing continuous assessment.	10.0	2.25
S-38	identifying educational objectives.	10.0	3.00
S-50	lessons where science content is taught through engineering practices.	9.5	2.00

Table 17

Round 2 & 3 (Sec3-Q Strategy) 71 Accepted Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
S-69	understanding how engineering and science concepts function.	9.5	2.00
S-20	developing age and grade appropriate engineering design challenges.	9.5	2.25
S-58	problem based learning activities.	9.5	2.25
S-71	understanding science concepts.	9.5	2.00

Table 17 (continued)

Round 2 & 3 (Sec3-Q Strategy) 71 Accepted Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
S-60	providing resources such as websites, handouts, expert guest speakers, etc.	9.5	2.25
S-41	implementing age and grade appropriate engineering design challenges.	9.5	2.50
S-26	establishing collaboration between science teacher educators and technology and engineering teacher educators.	9.5	3.25
S-73	understanding STEM engagement.	9.5	3.50
S-76	utilizing professional journals to explore teaching pedagogies.	9.5	3.50
S-51	making comparisons, (e.g., what commonalities and differences do systems have?)	9.0	1.25
S-13	critiquing science lessons to identify engineering content.	9.0	2.00
S-3	applying engineering practices to a problem clearly linked to science content.	9.0	2.00
S-54	managing open-ended, multiple solution problems.	9.0	2.00
S-67	technological problem solving techniques.	9.0	2.00
S-74	understanding the concepts of engineering design as in described in the NGSS.	9.0	2.00
S-12	critiquing engineering lessons to identify science content.	9.0	2.25
S-57	participating in science lessons as K-12 students.	9.0	2.25
S-27	examining the engineering design process as a content method.	9.0	2.75
S-33	formative assessment of open ended engineering problems.	9.0	2.75

Table 17 (continued)

Round 2 & 3 (Sec3-Q Strategy) 71 Accepted Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
S-72	understanding STEM content learning.	9.0	2.75
S-47	iterative engineering design activities.	9.0	3.25
S-52	making predictions, (e.g., based on what has been observed, what is known about a specific system, and what is known about related scientific principles, make a prediction about what will happen next.)	9.0	3.50
S-53	managing group-oriented projects.	9.0	3.50
S-62	the same things used to teach technology and engineering teachers.	9.0	3.50
S-78	utilizing STEM to solve social problems.	9.0	3.50
S-25	distinguishing between engineering and science concepts.	9.0	4.00
S-36	identifying engineering situations that enable the integration of science lessons.	8.5	1.50
S-18	determining engineering problems.	8.5	1.75
S-14	experiencing exemplary engineering design activities.	8.5	2.00
S-37	identifying and discuss cross-disciplinary intersections between science, technology, and engineering education.	8.5	2.25
S-39	the process of identifying key science content.	8.5	2.25
S-49	lessons and activities where students are faced with an engineering problem.	8.5	2.25
S-56	modeling integrating science teaching in engineering design.	8.5	2.25

Table 17 (continued)

Round 2 & 3 (Sec3-Q Strategy) 71 Accepted Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
S-15	designing engineering solutions.	8.5	3.00
S-1	analyzing the appropriateness of an engineering design activity.	8.5	3.25
S-2	analyzing the effectiveness of an engineering design activity.	8.5	3.25
S-22	developing standards-based engineering activities.	8.5	3.25
S-6	authentic science problem solving activities.	8.5	3.25
S-65	summative assessments.	8.5	3.25
S-70	understanding inquiry.	8.5	3.25
S-10	cooperative learning.	8.5	3.75
S-23	developing standards-based engineering experiences.	8.5	4.00
S-35	hands on/minds on science activities.	8.5	4.00
S-8	content knowledge identified in the NGSS.	8.5	4.00
S-42	inquiry based activities.	8.0	1.50
S-44	the use of science rubrics such as the dimensions of success tool to measure student engagement.	8.0	1.50
S-24	discussing STEM concepts associated with the activity or experience.	8.0	2.25
S-55	short video clips or actual teaching sequences to illustrate how a master teacher uses the design activity to teach targeted science content.	8.0	2.25

Table 17 (continued)

Round 2 & 3 (Sec3-Q Strategy) 71 Accepted Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
S-40	identifying STEM concepts associated with the activity or experience.	8.0	2.50
S-61	recognizing probable outcomes, (e.g., how will the system react to a specific action?)	8.0	2.50
S-66	teaching sequences utilizing design activities.	8.0	2.50
S-7	the *NGSS* to identify how the design process can be used to teach specific content by combining different standards and benchmarks.	8.0	2.75
S-30	exposing student teachers to scientific phenomena.	8.0	3.00
S-34	framing engineering design activities as a tool for getting to the science content objectives of the *NGSS* standard we're addressing.	8.0	3.00
S-77	utilizing science to solve engineering problems.	8.0	3.00
S-80	utilizing the pedagogical approach of modeling science curriculum.	8.0	3.00
S-11	creating tools and instrumentation for collecting scientific data.	8.0	3.25
S-19	determining science questions.	8.0	3.25
S-68	understanding cause and effect relationships.	8.0	3.25
S-9	contrasting processes used by scientists with those used by professionals in other disciplines.	8.0	3.25
S-63	science-specific pedagogical approaches.	8.0	3.50
S-16	designing investigative science solutions.	7.5	3.50
S-17	designing science lesson plans, teaching and then reflecting on these lessons.	7.5	3.75

Table 17 (continued)

Round 2 & 3 (Sec3-Q Strategy) 71 Accepted Instructional Strategies

Question #	*Instructional Strategies*	Median	IQR
S-28	examining the engineering design process as a pedagogical method.	7.5	4.00
S-29	exhibiting techniques for questioning different phenomena.	7.5	4.00
S-5	approaching engineering as a way of thinking.	7.5	4.00
S-64	scientific argumentation.	7.5	4.00

Summary of Delphi Results

This study employed the use of a three round modified Delphi. During each round, the Delphi Questionnaire was divided in to three separate sections that corresponded with each of the research questions. As a result, a group of science and technology education experts identified the characteristics of a methodological framework for preparing science educators to implement design-based engineering practices to intentionally teach targeted science content.

As indicated in Table 18, during Round 2, consensus was reached on 341 (about 80%) of all Round 1 items: 283 were accepted and 58 rejected. The remaining 87 items (Table 19) constituted the Round 3 Questionnaire.

Table 18

Summary of Results of Data Analysis for Round 2

	n from Round 1	Accepted	Rejected	Round 2Non-Consensus Statements
Sec 1-QA	80	47	14	19
Sec 1-QB	102	52	24	26
Sec 2-QA	89	61	10	18
Sec 2-QB	75	59	5	11
Sec 3-Q Strategy	82	64	5	13
Total	428	283	58	87

Table 19

Summary of Results of Data Analysis for Round 3

	n from Round 2	Accepted	Rejected	Round 3 Non-Consensus Statements
Sec 1- QA	19	6	5	8
Sec 1- QB	26	7	7	12
Sec 2- QA	18	7	8	3
Sec 2- QB	11	3	1	7
Sec 3- Q Strategy	13	7	2	4
Total	87	31	22	34

As shown in Table 19, the panel reached consensus regarding an additional 53(12.4%) items during Round 3. Of these 52 items panelists agree 31(7.24%) should be included in the framework and 22 (5.1%) (Appendix K) should not. This totaled 313 (73.1%) items panelist reached consensus on that they agreed should be included in the framework. Ultimately, stability was reached on all non-consensus by the end of Round 3 (i.e., item change <15%). Of the 428 Round 1 statements, the panel failed to reach consensus on 34 (7.9%) items (Appendix M). See Table 20 for a total of all accepted framework items.

Table 20

Total # of all Round 2 and 3 Accepted Framework Items

Total	Section and Question Number
53	Section 1. Question A - Practice 1 Competency (Sec1-QA)
59	Section 1. Question B - Practice 1 Strategy (Sec1-QB)
68	Section 2. Question A - Practice 6 Competency (Sec2-QA)
62	Section 2. Question B - Practice 6 Strategy (Sec2-QB)
71	Section 3. Question Strategy - Instructional Strategies (Sec3-Q Strategy)

In summary, the results of data analysis provide this study with three essential points of data. First are the items panelists agreed “should” be considered as competencies all K-12 pre-service science teachers must possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** and ***DESIGN engineering SOLUTIONS*** as a practice they would teach students. Second, are the items panelists agreed “should” be considered as instructional strategies teacher educators should use when preparing K-12 pre-service science teachers to teach students ***the practice of DEFINING engineering PROBLEMS*** and ***DESIGNING engineering SOLUTIONS.*** Lastly, are the instructional strategies teacher educators should use when preparing K-12 pre-service science teachers to ***intentionally teach targeted science content*** through engineering practices. These results reflect what this select panel of science and technology experts identified as the essential characteristics of a methodological framework that can serve to prepare K-12 science educators on the implementation of design-based engineering practices that *intentionally* teach targeted science content.

CHAPTER V: CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Presented in this chapter are the data-driven conclusion, followed by discussion, and implications drawn from those conclusions. The chapter ends with recommendations for further research.

Conclusions

The *Next Generation Science Standards (NGSS)* necessitates that science educators use engineering practices when teaching K-12 science content. The purpose of this study was to characterize a methodological framework for preparing pre-service K-12 science educators to implement design-based engineering practices to *intentionally* teach targeted science content.

As Chapter 4 describes in detail, each of the three research questions for this study were examined through the use of a 3 Round modified on-line Delphi. During each round, Delphi Questionnaires were divided into 3 separate sections and designed to address each of the research questions in order.

Section 1 – *NGSS* Practice 1: Defining Engineering Problems

Section 2 – *NGSS* Practice 6: Designing Engineering Solutions

Section 3 – Intentional Teaching of Science Content Through Engineering Practices.

Below, conclusions are presented in order of these sections. Each segment begins by restating the research question and then proceeds with the data-driven conclusions for that question. Each segment concludes with a discussion of these conclusions.

Defining Engineering Problems: Research Question 1

How should teacher educators prepare K-12 pre-service science teachers to *define engineering* problems as one of eight *NGSS* practices all students should acquire through science education?

Conclusion 1. Using the Delphi method, a panel of science and technology teacher educators were successful in identifying 53 competencies (Table 13, p. 112-114) all pre-service K-12 science teachers should attain to be adequately prepared to define engineering problems as reflected in Practice 1 of the *NGSS*.

Conclusion 2. Results indicated that 29 of the 53 (55%) accepted *NGSS* Practice 1 Competencies received one of the highest three possible ratings (9.0, 9.5, and 10.0; Table 13, pp. 112-114) by the panel of experts. One can therefore conclude that these 29 Practice 1 Competencies represent those most critical for inclusion in any methodological framework designed to prepare K-12 pre-service science teachers to define engineering problems and meet their *NGSS* Practice 1 requirement.

Specifically, it can be concluded that all pre-service K-12 science teachers should exit their preparation programs possessing the ability to use design-based engineering practices to effectively define engineering problems as characterized in these 29 competency statements. From this, one would also conclude that in order to prepare future teachers, science teacher educators will need to themselves develop a deep understanding of how design-based engineering practices can be used to define engineering problems. This would be inclusive of their capacity for designing and implementing instructional strategies that prepare pre-service science teachers to design and implement design based engineering lessons that teach K-12 students to accurately define engineering problems as an engineering practice.

Conclusion 3. Using the Delphi method, a panel of science and technology teacher educators were successful in identifying 59 instructional strategies (Table 14, p. 117) teacher educators should use when preparing pre-service science teachers to teach K-12 students the practice of defining engineering problems as reflected in Practice 1 of the *NGSS*.

Conclusion 4. Results indicated that 27 of the 59 (46%) accepted *NGSS* Practice 1 Instructional Strategies received ratings between 9.0 and 10.0. Form these findings one can conclude that these 27 Practice 1 Instructional Strategies represent those most critical for inclusion in any methodological framework designed to prepare K-12 pre-service science teachers to define engineering problems and meet their *NGSS* Practice 1 requirement.

Specifically, it can be concluded that all pre-service K-12 science teachers should exit their preparation programs possessing the ability to use design-based engineering practices to effectively define engineering problems as characterized in these 27 instructional strategies statements. From this, one would also conclude that in order to prepare future teachers, science teacher educators will need to themselves develop a deep understanding of how design-based engineering practices can be used to define engineering problems. This would be inclusive of their capacity for designing and implementing instructional strategies that prepare pre-service science teachers to design and implement design based engineering lessons that teach K-12 students to accurately define engineering problems as an engineering practice.

Design Engineering Solutions: Research Question 2

How should teacher educators prepare K-12 pre-service science teachers to *design engineering* solutions as one of eight NGSS practices all students should acquire through science education?

Conclusion 5. Using the Delphi method a panel of science and technology teacher educators were successful in identifying 68 competencies (Table 15, p. 122) that all pre-service K-12 science teach should acquire to be adequately prepared to design engineering solutions as reflected in Practice 6 of the *NGSS*.

Conclusion 6. Results indicated that 35 of the 68 (51%) accepted *NGSS* Practice 6 Competencies had a rating between 9.0 and 10.0 and approximates the top half of all accepted competencies as identified by the panel of experts. Thus, based on this finding one can conclude that these 35 Practice 6 Competencies represent those most critical for inclusion in any methodological framework designed to prepare K-12 pre-service science teachers to design engineering solutions and meet their *NGSS* Practice 6 requirement.

Specifically, it can be concluded that all pre-service K-12 science teachers should exit their preparation programs possessing the ability to use design-based engineering practices to effectively design engineering solutions as characterized in these 35 competency statements. From this, one would also conclude that in order to prepare future teachers, science teacher educators will need to themselves develop a deep understanding of how design-based engineering practices can be used to define engineering problems. This would be inclusive of their capacity for designing and implementing instructional strategies that prepare pre-service science teachers to design and implement design based engineering lessons that teach K-12 students to accurately design engineering solutions as an engineering practice.

Conclusion 7. Using the Delphi method, a panel of science and technology teacher educators were successful in identifying 62 instructional strategies (Table 16, p. 128) teacher educators should use when preparing K-12 pre-service science teachers to teach students the practice of designing engineering solutions as reflected in Practice 6 of the *NGSS*.

Conclusion 8. Results indicated that 33 of the 62 (53%) accepted *NGSS* Practice 6 Instructional Strategies had a rating between 9.0 and 10.0. From this point forward in this conclusion these 33 Practice 6 Instructional Strategies represent those most critical for inclusion in any methodological framework designed to prepare K-12 pre-service science teachers to design engineering solutions and meet their *NGSS* Practice 6 requirement.

Specifically, it can be concluded that all pre-service K-12 science teachers should exit their preparation programs possessing the ability to use design-based engineering practices to effectively design engineering solutions as characterized in these 33 instructional strategies statements. From this, one would also conclude that in order to prepare future teachers, science teacher educators will need to themselves develop a deep understanding of how design-based engineering practices can be used to design engineering solutions. This would be inclusive of their capacity for designing and implementing instructional strategies that prepare pre-service science teachers to design and implement design based engineering lessons that teach K-12 students to accurately design engineering solutions as an engineering practice.

Instructional Strategies to Intentionally Teach Science Content : Research Question 3

> How should teacher educators prepare K-12 pre-service science teachers to *intentionally* teach targeted science content using their newly acquired abilities to define engineering problems and design engineering solutions?

Conclusion 9. Using the Delphi method, a panel of science and technology teacher educators were successful in identifying 71 instructional strategies (Table 17, p.133) teacher educators should use when preparing K-12 pre-service science teachers to *intentionally* teach targeted science content through engineering practices.

Conclusion 10. Results indicated that 30 of the 71 (42%) accepted instructional strategies to intentionally teach science content had a rating between 9.0 and 10.0 and approximates the top half of all the accepted instructional strategies as identified by the panel of experts. Thus, based on this finding one can conclude these 30 instructional strategies represent those most critical for inclusion in any methodological framework designed to prepare K-12 pre-service science teachers to intentionally teach science content.

Specifically, it can be concluded that all pre-service K-12 science teachers should exit their preparation programs possessing the ability to use design-based engineering practices to intentionally teach science content as characterized in these 30 instructional strategies statements. From this, one would also conclude that in order to prepare future teachers, science teacher educators will need to themselves develop a deep understanding of how design-based engineering practices can be used to intentionally teach science content. This would be inclusive of their capacity for designing and implementing instructional strategies that prepare pre-service science teachers to design and implement design based engineering lessons that teach K-12 students to learn science content as an engineering practice.

Conclusion 11. Finally, results suggest value in redesigning pre-service K-12 science teacher educations programs by implementing design-based engineering practices to teach science.

Implications

There are several implications that can be drawn from this study's findings. As noted in the *NGSS* the preparation of pre-service science teachers has been grounded in the teaching pedagogy of scientific inquiry. As discussed earlier in this document, science educators have a tradition of teaching science by presenting well-defined science phenomena problems, which are then supported through the use of experimentation that demonstrate science theory. However, findings from the current study suggest that the competencies pre-service K-12 science teachers must acquire in order to implement the *NGSS* as intended will necessitate knowledge of designed-based engineering practices to *intentionally* teach targeted science content.

Implication 1. This implies that to accomplish this, science educators preparing pre-service science educators will need to modify their current methods of instruction to intentionally teach these engineering practices.

Implication 2. Furthermore, it implies that higher education pre-service programs must reexamine their current curricula and make necessary modifications to address new engineering practice requirements for K-12 science teacher education programs.

Implication 3. The use of design-based engineering practices to teach science will also require professional development of in-service science educators. As explored in the literature review of this study, the NRC found that many teachers were pleased with the integration of engineering and technology in the standards; however there concerns remained (NRC, 2012, p. 337). Teachers were apprehensive about the amount of space dedicated to engineering and technology, the core ideas the *Framework* recognized, and the ability to teach these concepts in K-12 (NRC, 2012, p.337). These factors will require current teachers to be instructed in the use of design based-engineering practices. As with any change in education this will take time and the willingness of science educators to effectively implement this change.

Implication 4. Finally, study findings have implications regarding the growth of and demand for Integrative STEM Education programs. The *NGSS* do not specify that engineering practices are to be solely taught by science educators. To the contrary, they emphasize what students ought to know and be able to do as a result of science education. These engineering practices are also specifically targeted within other pre-service education disciplines. For example, following the national Standards for Technological Literacy (ITEEA, 2000/2002/2007), technology and engineering pre-service education programs have been preparing pre-service teachers in the use of design-based engineering practices to teach problem solving for nearly two decades. This implies that technology and science education pre-service preparation programs should align their respective pre-service curricula and collaborate in promoting the development of pre-service students exiting with full competence in teaching engineering practices revealed through this research.

Recommendations

Recommendations for practice and future research are as follows.

Practice Recommendations

1. Further research is needed to determine how the critical competencies and instructional strategies identified in this study should be used to construct a methodological framework for preparing pre-service K-12 science teachers.
2. Further research is needed on how to incorporate these competencies and instructional strategies in to professional development opportunities for in-service science teachers.

3. Additional research is needed to delineate ways that science and technology can work together in designing integrative STEM education curriculum.

Research Recommendations

1. Replications of this study might adjust recruitment and retention of panel members in science education. The majority of panelists who participated in this study were from the discipline of technology and engineering education. A panel with better representation from the science community may provide more insight on this issue
2. Further study is needed to gauge the degree of shift away from the teaching practice of scientific inquiry is necessary.
3. Future studies may examine how to sufficiently assess the competencies highlighted in the study.
4. Additional research is needed to assess science teacher educators' current knowledge in and ability to utilize design-based engineering practices in the preparation of K-12 science teachers.

Recommendations to Professional Organizations

1. Professional organizations might use the results of this study to further examine and establish a methodological framework for preparing not only K-12 science teacher educators but other educators as well.
2. Local and state organizations might use the results of this study as a call to action in the redesign and implementation of design-based engineering practices within their current programs. Existing curriculums should be examined to assess if the current content of the programs being offered at the K-12 level is addressing the needs of the students as outlined in the science and technology education standards.

3. Institutions of higher learning should examine the current status of their science and technology education programs to determine how effectively they are preparing educators with the competencies and instructional strategies identified as critical in this study.
4. It is also a recommendation of this study that further research be conducted to determine if Practices 1 and 6 of the *NGSS* should only be taught by science teacher educators in K-12 science teacher education programs or these practices could be taught by technology teacher educators to all.

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APPENDICES

Appendix A

Consent Form

Round 1

I have read the invitation letter associated with this study and meet the minimum panel criteria. I fully understand the nature of this commitment and intend to do my best to fulfill all of the obligations associated with this study. I also understand that I may withdraw from this study at any time without consequences of any kind. Please type your name in the bellow to accept this agreement.

Electronic Signature:

First Name

Last Name

Address:

City/Town:

State:

Zip/Postal Code:

Country:

E-mail:

Phone Number:

Title:

Organization or Affiliation:

How many years have you been preparing teachers in higher education science, technology or engineering education?

Are you currently addressing the knowledge, skills and attitudes reflected in the *Next Generation Science Standards* (NGSS Lead States, 2013) in the preparation of pre-service teachers?
Yes ☐ No ☐

Have you recently published or presented research in the field, teacher education, curriculum design, and/or teacher training? Yes ☐ No ☐

Have you recently obtained funding or provided professional development in the areas of science, technology or engineering education? Yes ☐ No ☐

Questions About the Study Please Contact:

James S. Carlson
Ph.D. Student
Integrative STEM Education
Department of Teaching and Learning
Virginia Tech
52 Old Ponsett Road
Haddam, CT 06438
ph. 860.554.5398
carlsonj@vt.edu

Should you have any questions or concerns about the study& rsquo;s conduct or your rights as a research subject, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

Rounds 2 & 3

I fully understand the nature of this commitment and intend to do my best to fulfill all of the obligations associated with this study. I also understand that I may withdraw from this study at any time without consequences of any kind. Please type your name in the bellow to accept this agreement.

Electronic Signature: ☐

First Name: ☐

Last Name: ☐

Questions About the Study Please Contact:

James S. Carlson
Ph.D. Student
Integrative STEM Education
Department of Teaching and Learning
Virginia Tech
52 Old Ponsett Road
Haddam, CT 06438
ph. 860.554.5398
carlsonj@vt.edu

Should you have any questions or concerns about the study& rsquo;s conduct or your rights as a research subject, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

Appendix B

Teacher Education Preparation Programs

Listing of Science Education Programs

Adelphi University
American University
American University
Andrews University
Arkansas State University
Arkansas Tech University
Ashland University
Aurora University
Baylor University
Bluefield State College
Bowling Green State University
Bradley University
Butler University
Cameron University
Canisius College
Capital University
Cedarville University
Central Connecticut State University
Chicago State University
Clarion University of Pennsylvania
Clemson University
Clemson University
Cleveland State University
Coastal Carolina University
Coker College
Concord University
Concordia University Chicago
Converse College
Delta State University
East Central University
East Stroudsburg University
Eastern Connecticut State University
Eastern Illinois University
Eastern Michigan University
Edinboro University of Pennsylvania
Fairfield University
Fairmont State University
Fitchburg State University

Listing of Science Education Programs

Fordham University
Framingham State University
Framingham State University
Franciscan University of Steubenville
Furman University
George Mason University
George Washington University
Glenville State College
Governors State University
Graceland University
Grambling State University
Grand Valley State University
Harding University
Harris-Stowe State University
Heidelberg University
Hiram College
Hunter College of the City University of New York
Illinois State University
Indiana State University
Indiana University Northwest
Indiana University Northwest
Indiana University of Pennsylvania
Indiana University South Bend
Indiana University Southeast
Indiana Wesleyan University
Iona College - New Rochelle
Ithaca College
John Carroll University
Kean University
Keene State College
Kennesaw State University
Kent State University
King's College
Kutztown University of Pennsylvania
Langston University
Lehman College-CUNY
Lehman College-CUNY
Lewis University

Listing of Science Education Programs

Liberty University
Lock Haven University of Pennsylvania
Louisiana State University and A&M College
Louisiana Tech University
Loyola University Chicago
Loyola University Maryland
Luther College
Marietta College
Marywood University
McDaniel College
McKendree University
Mercy College
Metropolitan State University of Denver
Miami University
Millersville University of Pennsylvania
Mississippi College
Mississippi State University
Mississippi University for Women
Monmouth University
Montclair State University
Morris College
Mount Saint Mary College
Mount Saint Mary College
Mount Vernon Nazarene University
National-Louis University
Niagara University
Northeastern Illinois University
Northeastern State University
Northern Arizona University
Northern Illinois University
Notre Dame College
Notre Dame of Maryland University
Nova Southeastern University
Oakland City University
Ohio Dominican University
Ohio University
Oklahoma Baptist University
Oklahoma State University

Listing of Science Education Programs

Oklahoma Wesleyan University
Old Dominion University
Olivet Nazarene University
Oral Roberts University
Otterbein University
Otterbein University
Purdue University
Queens College
Quinnipiac University
Rider University
Roosevelt University
Rowan University
Sacred Heart University
Saint Louis University
Saint Mary's College
Saint Thomas Aquinas College
Saint Xavier University
Salem State University
Salem State University
Salisbury University
Sam Houston State University
Seton Hall University
Shawnee State University
Shepherd University
Shippensburg University of Pennsylvania
Siena College
Slippery Rock University of Pennsylvania
Southeast Missouri State University
Southeastern Louisiana University
Southeastern Oklahoma State University
Southern Connecticut State University
Southern Illinois University at Carbondale
Southern Illinois University Edwardsville
Southern Nazarene University
Southwestern Oklahoma State University
St. John Fisher College
State Univ of New York at Potsdam
State University of New York at Fredonia

Listing of Science Education Programs

State University of New York at Geneseo
State University of New York at New Paltz
State University of New York at Oswego
State University of New York at Potsdam
State University of New York College at Brockport
State University of New York College at Old Westbury
State University of New York College at Oneonta
Stony Brook University
SUNY Buffalo State
SUNY Buffalo State
SUNY Cortland
Syracuse University
Taylor University
Teachers College Columbia University
Texas Southern University
The Citadel The Military College of South Carolina
The City College of New York
The College of Charleston
The College of New Jersey
The College of Saint Rose
The Johns Hopkins University
The Ohio State University
The University of Dayton
The University of Memphis
The University of Oklahoma
The University of Science and Arts of Oklahoma
The University of Southern Mississippi
The University of Texas at Brownsville
The University of Toledo
The University of Vermont
The University of Wyoming
Towson University
Universidad De Puerto Rico De Cayey
Universidad De Puerto Rico De Mayagüez
Universidad De Puerto Rico-Rio Piedras Campus
University of Akron
University of Alaska Fairbanks
University of Arkansas - Fort Smith

Listing of Science Education Programs

University of Arkansas at Little Rock
University of Arkansas, Fayetteville
University of Central Arkansas
University of Central Missouri
University of Central Oklahoma
University of Cincinnati
University of Colorado Springs
University of Connecticut
University of Delaware
University of Findlay
University of Hawaii at Manoa
University of Louisiana at Lafayette
University of Louisiana at Monroe
University of Maryland Baltimore County
University of Maryland College Park
University of Maryland Eastern Shore
University of Massachusetts Amherst
University of Massachusetts Lowell
University of Mount Union
University of Rhode Island
University of Rochester
University of Saint Joseph
University of South Carolina
University of South Carolina Upstate
University of South Carolina-Aiken
University of St. Francis
University of Texas at Arlington
University of Texas of the Permian Basin
Valparaiso University
Vincennes University
Wagner College
Walsh University
West Chester University
West Virginia State University
West Virginia University
Western Connecticut State University
Western Governors University
Western Illinois University

Listing of Science Education Programs

Western Michigan University
Westfield State University
Westfield State University
Wheaton College
William Paterson University
Winthrop University
Wittenberg University
Wittenberg University
Wright State University
Youngstown State University

Listing of Technology/Engineering Education Programs

Appalachian State University
Ball State University *
Berea College
Brigham Young University
Buffalo State College *
California University of Pennsylvania
Central Connecticut State University *
Central Washington University
Colorado State University
Eastern Illinois University *
Eastern Kentucky University
Eastern Kentucky University
Eastern Michigan University *
Fitchburg State University *
Fort Hays State University
Hofstra University
Illinois State University *
Indiana State University *
Johnson & Wales University
Kent State University
Millersville University of PA
Montana State University
New York City College of Technology
North Carolina State University
Ohio Northern University
Old Dominion University *
Pittsburg State University
Purdue University *
Rhode Island College *
Southwestern Oklahoma State University
St. Cloud State University
State University of NY at Oswego
Texas State University
The College of New Jersey *
The Ohio State University
Tufts Center for Engineering Education and Outreach
University of Arkansas
University of Central Missouri
University of Georgia
University of Idaho
University of Maryland Eastern Shore *
University of Northern Iowa
University of Wisconsin-Stout
Utah State University
Valley City State University

* Indicates a CAPE Approved School

Appendix C

Institutional Review Board Approval

VirginiaTech

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: March 18, 2016

TO: John Wells, James Starr Carlson

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Preparing Educators to Employ Design-Based Engineering Practices in K-12 Science

IRB NUMBER: **16-266**

Effective March 18, 2016, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Exempt, under 45 CFR 46.110 category(ies) 2,4**
Protocol Approval Date:	**March 18, 2016**
Protocol Expiration Date:	**N/A**
Continuing Review Due Date*:	**N/A**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

Appendix D

Delphi Panel Participant Pool

Science Pool

University	*Program Contacted*
Adelphi University	Adolescence Education
American University	Institute for Innovation in Education
Andrews University	Science Education
Baylor University	School of Education
Bluefield State College	School of Education
Buffalo State University	Earth Science and Science Education
Canisius	Adolescence Education
Central Connecticut State University	Science Education, and Assessment
Chicago State	College of Education
Clarion University	School of Education
Clemson University	Engineering and Science Education
Columbia University	Adolescent Earth Science Education
Concordia University Chicago	College of Education
Delta State University	Science Education
East Stroudsburg University	Department of Physics
Eastern Connecticut State University	School of Education
Eastern Illinois University	College of Education & Professional Studies
Edinboro University of Pennsylvania	Middle and Secondary Education, and Educational Leadership Department
Edwardsville Southern Illinois University	STEM Center
Fairfield University	School of Education
Fitchburg State University	Science and Social Studies for Students, Special Education, Assessment Science Education
Fordham University	Graduate School of Education
Furman University	School of Education
George Washington University	Elementary Education
Governors States University	Coordinator of Secondary Science Education Programs
Grambling State University	School of Education
Grand Valley State University	Integrated Science
Harding University	STEM Center for Math and Science Education
Harris-Stowe State University	Unified Science
Heidelberg University	School of Education
Hunter College	Adolescent Earth Science Education
Indiana State University	Center for Science Education

Science Pool

University	*Program Contacted*
Indiana University Northwest	School of Education
Indiana University of Pennsylvania	College of Education and Educational Technology
Indiana Wesleyan University	Biology School of Education Natural Sciences Chemistry Physical and Applied Science
Keene State College	General Science Center for Science and Technology in Education
Kennesaw State University	Bagwell College of Education
King’s College	Department of Education
Leham College-CUNY	School of Education
Lewis University	College of Education
Louisiana State University and A&M College	Department of Physics
Louisiana Tech University	Department of Curriculum, Instruction, and Leadership
Loyola University Chicago	Science Education
Luther College	Education Department
Metropolitan State University of Denver	School of Education
Michigan State University	College of Education
Millersville University of Pennsylvania	STEM Education Center
Montclair State University	Science Education
National Louis University	Science Education
Northeastern State University	School of Science
Northern Arizona University	Center for Science Teaching and Learning
Northern Illinois University	Department of Biological Sciences Department of Chemistry and Biochemistry Department of Geology and Environmental Geosciences Ruthann Yeaton in Health Services Department of Physics
Notre Dame College	Biology
Notre Dame of Maryland University	School of Education
Ohio Dominican University	Adolescent to Young Adult

Science Pool

University	*Program Contacted*
Oklahoma Baptist University	School of Science
Olivet Nazarene University	Chemistry and Geoscience
	School of Education
	Chemistry and Geoscience
	School of Education
	School of Engineering and Technology
	Biological Sciences
Oral Roberts University	College of Science and Engineering
Otterbein University	Department of Biology and Earth Science
Purdue	Department of Curriculum & Instruction
Quinnipiac University	Associate Professor of Education, School of Education
	Science
Rider University	GEMS
Rowan University	Department of STEAM
	Science Education
	Middle School Science Education
Saint Xavier University	School of Education
Salisbury University	Seidel School of Education and Professional Studies
Sam Houston State University	Curriculum & Instruction
Shepherd University	School of Education
	College of Education and Human Services
Shepherd University	Department of Learning Sciences and Human Development
Southern Connecticut State University	School of Education
Southwestern Oklahoma State University	Education Department
St. Francis	College of Education
State University of New York at Fredonia	Director Science Education Partnership, Science Education
State University of New York College at Brockport	Department of Education and Human Development
State University of New York College at Old Westbury	Science Education
Stony Brook University	Science Education
The Citadel The Military College of South	Biology

Science Pool

University	*Program Contacted*
Carolina	Chemistry
The City College of New York	School of Education
The College of Charleston	Department of Physics and Astronomy Department of Teacher Education
The College of New Jersey	Science Complex
The Ohio State University	Department of Human Sciences
The University of Science and Arts of Oklahoma	Science and Physical Education
Towson University	College of Education
University of Arkansas at Little Rock	College of Education
University of Arkansas, Fayetteville	College of Education and Health Professions
University of Central Arkansas	College of Natural Sciences and Mathematics
University of Colorado Springs	College of Education
University of Connecticut	NEAG School of Education
University of Delaware	Delaware Center For Teacher Education Professor, Department of Chemistry & Biochemistry
University of Louisiana at Lafayette	School of Education
University of Louisiana at Monroe	School of Education
University of Maryland Baltimore County	School of Education
University of Maryland College Park	College of Education
University of Massachusetts Lowell	Graduate School of Education
University of Rhode Island	School of Education
University of Rochester	School of Education
University of South Carolina	Department of Educational Studies Science Education School of Education
University of South Carolina-Aiken	Science Department
University of Texas at Austin	Department of Curriculum and Instruction, STEM Education
University of Wisconsin-Madison	Department of Liberal Arts and Applied Studies
Vincennes University	Summers Center
Wagner	School of Education
Western Connecticut State University	School of Education
Westfield State University	Chemical and Physical Science
Wheaton College	Wheaton Education Department

Science Pool

University	*Program Contacted*
William Paterson University	College of Education
Wittenberg University	Science Education
Wright State University	The College of Science and Technology

Technology/Engineering Pool

Institution	*Program Contacted*
Appalachian State University	Undergraduate Coordinator Technology Education Program Graduate Coordinator, Technology Education Program
Ball State University	Technology & Engineering Education Department of Technology Chair of the Technology and Applied Design Program
Black Hills State University	Provost and Vice President for Academic Affairs
Brigham Young University	Technology and Engineering Education Graduate Program
Buffalo State College	Chair and Associate Professor
California University of Pennsylvania	Professor Technology Education Assistant Professor Technology Education Dean of College of Science & Technology Professor & Interim Associate Provost & Vice President Professor Technology Education
California University of Pennsylvania	Professor Technology Education
Central Connecticut State University	Technology & Engineering Education
Central Washington University	Hogue Technology
Colorado State University	Engineering Science/Engineering Education
Eastern Illinois University	Technology Education Department
Eastern Kentucky University	Department of Applied Engineering and Technology
	Applied Engineering and Technology
Eastern Michigan University	Associate Professor of School of Technology Studies Technology Education
Fitchburg State University	Department of Technology
Fort Hays State University	Department of Applied Technology
Hofstra University	Center for STEM Education Research
Illinois State University	Associate Professor Technology & Engineering Education Professor & Coordinator Technology & Engineering Education
Indiana State University	Dean of Technology Education Assistant Professor
Johnson & Wales University	School of Engineering & Design
Kent State University	College of Applied Engineering, Sustainability, and Technology
Millersville University of PA	Department Chair, Applied Engineering, Safety & Technology Program Coordinator, Technology Education
New York City College of	Chair, Technology Teacher Education

Technology/Engineering Pool

Institution	*Program Contacted*
Technology	
New York City College of Technology	Technology Teacher Education
North Carolina State University	Teaching Associate Professor Technology, Engineering & Design Education Professor Technology, Engineering & Design Education Associate Professor Technology, Engineering & Design Education Professor Emeritus Technology, Engineering & Design Education Assistant Professor Technology, Engineering & Design Education Professor Technology, Engineering & Design Education
Ohio Northern University	Department of Technological Studies
Old Dominion University	Industrial Technology Program Director Professor Technology Education Program Director
Pittsburg State University	Department of Technology and Workforce Learning
Purdue University	Professor Associate Professor and Coordinator Associate Professor
Rhode Island College	Program Coordinator/TECH
Southwestern Oklahoma State University	Chair Technology Education
St. Cloud State University	Associate Dean of College if Science and Engineering Technology Education
State University of NY at Oswego	Technology Education Associate Professor Integrative STEM Education Assistant Professor Integrative STEM Education Department Chair Integrative STEM Education
The Ohio State University	Professor of Technology Education Technology Education
Tufts Center for Engineering Education and Outreach	CEEO Director
University of Arkansas	Curriculum and Instruction
University of Central Missouri	Career and Technology Education
University of Georgia	College of Education
University of Idaho	Engineering and Technology Education
University of Maryland, Baltimore	Dean, College of Engineering and Information

Technology/Engineering Pool

Institution	*Program Contacted*
County	Technology
University of Maryland Eastern Shore	Coordinator Graduate Studies Chairperson of the Department of Technology & Engineering Program Coordinator and Assistant Professor
University of Northern Iowa	Department of Technology
University of Wisconsin-Stout	Technology Education Program/School of Education
Utah State University	Technology and Engineering Education
Valley City State University	Technology Education Department

Appendix E

Invitation Email

Dear Teacher Educator,

My name is James Carlson and I am writing to ask for your help in addressing a very important teacher preparation issue related to the Next Generation Science Standards. The issue I am referring to is the preparation of pre-service science educators for adequately addressing the engineering practices that are now part of the national science standards.

I am a doctoral student in the Integrative STEM Education program at Virginia Tech working with Dr. John Wells to conduct my dissertation research. The purpose of my research is to characterize a methodological framework for preparing pre-service science educators to implement design-based engineering practices to intentionally teach targeted science content. As no such framework currently exists to guide the preparation of science educators equipped to implement engineering practices within science education, the use of a forecasting method such as the Delphi is most appropriate.

The Delphi method is based on input from experts such as yourself on a given topic. In my review of potential participants, it is my belief that you have experience and/or expertise in preparing science educators that qualifies you as an individual with the expert insights regarding the implementation of design-based engineering practices in the K-12 science classroom. If I am correct that you meet at least 3 of the 5 criteria listed below I would like to invite you to participate as a member of an expert panel.

Panel members must meet 3 of the 5 following criteria:

1. Expertise in the teaching and learning of K-12 science, technology and/or engineering education.

2. Minimum of five years of teacher preparation experience in higher education in science, technology or engineering.

3. Currently addressing the knowledge, skills and attitudes reflected in the *Next Generation Science Standards* (NGSS Lead States, 2013) in the preparation of pre-service teachers.

4. Recently published or presented K-12 science education teaching and learning research in the field, which focuses on teacher education, curriculum design, and/or teacher training.

5. Demonstrated potential for funding in professional development in the areas of science, technology or engineering.

Participation in this study is completely voluntary and you may withdraw from the study at any time. Panelists will be asked to complete a short 20-30 minute questionnaire about every two weeks. This will continue until consensus is reached among the panel members. Most studies of this nature involve two to three rounds of questionnaires. All responses from the panel members will be kept confidential.

If you choose to participate in this study please click on the link below and complete the study participation agreement and the first round questionnaire by April 22, 2016. Should you have any questions or concerns, please feel free to contact me. If you have trouble opening these documents, please contact me with your name and mailing address and I will send you a hard copy to complete. Thank you for taking the time to assist me with my study.

Website Link: http://goo.gl/forms/mAq5zRqJ41

Sincerely,

James S. Carlson
Ph.D. Candidate
Integrative STEM Education
Department of Teaching and Learning
Virginia Tech
52 Old Ponsett Road
Haddam, CT 06438
ph. 860.554.5398
carlsonj@vt.edu

Should you have any questions or concerns about the study & rsquo;s conduct or your rights as a research subject, you may contact the VT IRB Chair, Dr. David M. Moore
at moored@vt.edu or (540) 231-4991.

Appendix F

Round 1 Questionnaire

Round 1 Instructions

Dear Delphi Panel Member,

Thank you for taking the time to assist me to identify the characteristics of a methodological framework that prepares science educators to implement design-based engineering practices that intentionally teach targeted science content. The success of this study is based on your experience and expertise in implementing design-based engineering practices in the K-12 classroom.

On the following pages will find a brief introduction explaining the context of the study, and a sample Round I Delphi question. After reviewing the introduction and the sample question, please continue to the last page and complete the Round I questionnaire.

Completing each of the Round I open ended questions should take 20-30 minutes. Please answer each of the items with as much detail as possible. If you have any questions feel free to contact me at carlsonj@vt.edu. Following my analysis of the Round I responses I will contact you with instructions for Round II of this study. My analysis should take about two weeks.

Thank you,

James S. Carlson
Ph.D. Candidate
Integrative STEM Education
Department of Teaching and Learning
Virginia Tech
52 Old Ponsett Road
Haddam, CT 06438
ph. 860.554.5398
carlsonj@vt.edu

Research Introduction

The implementation of engineering practices in science education according to the NRC will take shape in the form of teaching students engineering design (NRC, 2012, p. 42). *Next Generation Science Standards (NGSS)* identifies eight core practices essential for all K-12 students. These practices are highlighted in the first dimension (scientific and engineering practices) of the standards and focus on how the procurement of scientific knowledge requires the development of both science knowledge and skills. The eight core practices of science and engineering emphasized in the *NGSS* (2013b) are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information. (p. 48)

The objective of each of these practices intends to promote, extend, and/or enhance student learning by developing students' ability to use these skills in supporting and demonstrating their understanding of science and engineering (NRC, 2012, p. 49). The intent of integrating science and engineering practices in the *NGSS* is to provide science educators with guidance on how they can enhance their teaching to better fit the new standards. It allows for students to be engaged in the process of science and develops students' ability to acquire problem-solving skills. Although engineering practices are implied throughout the eight practices they are specifically addressed in practices 1 and 6.

NGSS require that K-12 science teachers have the ability to define engineering problems and design engineering solutions as two of eight practices they would teach in science and that all their students should be able to do. Practice 1 attempts to build science skills through the use of design-based engineering practices, Practice 6 focuses on engaging students in systematic processes (NGSS Lead States, 2013b, p. 60). The intent of including the engineering practices of defining problems and designing solutions in the *NGSS* is not to teach students engineering or engineering design, rather the goal is to utilize design-based engineering practices to engage students in activities that will enhance their understanding and application of science (NGSS Lead States, 2013b, p. 3).

Successful implementation of these standards necessitates teachers who have an understanding and the ability to implement design-based engineering practices to intentionally teach targeted science content. The purpose of this study is to characterize a methodological framework for preparing new science educators to implement design-based engineering practices to intentionally teach targeted science content. Data collected from this Delphi study will provide guidance on how to construct such a framework.

SAMPLE RESPONSES – Round 1

NGSS Practice 1: Defining *Engineering* Problems

In the text box provided below each of the open ended questions please write your responses providing as much detail as possible.

COMPETENCIES QUESTION:

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

SAMPLE RESPONSES

1. Teachers must be able to define multiple solutions to a problem that can be solved through the development of an object, tool, process, or system.

2. Teachers must be able to identify and compare the constraints of multiple solutions..

3. Teachers must be able to determine how possible solutions are limited by the materials and resources that are available.

4. Teachers should be able to communicate with others on the solutions presented and use feedback to improve the solution to a problem. Teachers should be able to provide this feedback to others as well.

STRATEGIES QUESTION:

What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DEFINING engineering PROBLEMS*** (strategies used to prepare them to teach that practice)?

SAMPLE RESPONSES

1. *Pre-service teachers should be engaged in hands on learning activities that model the teaching of a science problem that can be solved through the development of an object tool, process or system.*

2. *Engage pre-service teachers in learning experiences that challenge them to identify and analyze multiple constraints of multiple solutions to a problem.*

3. *Engage pre-service teachers in learning experiences that challenge them to determine how possible solutions are limited by the materials and resources that are available.*

4. *Engage pre-service teachers in learning experiences that allow them to communicate with others on the solutions presented and use feedback to improve the solution to a problem.*

SECTION ONE

NGSS PRACTICE 1: DEFINING *Engineering* PROBLEMS

In the text box provided below each of the open ended questions please write your responses providing as much detail as possible.

COMPETENCIES QUESTION:

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

STRATEGIES QUESTION:

What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DEFINING engineering PROBLEMS*** (strategies used to prepare them to teach that practice)?

SECTION TWO

NGSS PRACTICE 6: DESIGNING *Engineering* SOLUTIONS

In the text box provided below each of the open ended questions please write your responses providing as much detail as possible.

COMPETENCIES QUESTION:

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DESIGN engineering SOLUTIONS*** as a practice they would teach students?

STRATEGIES QUESTION:

What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DESIGNING engineering SOLUTIONS*** (strategies used to prepare them to teach that practice)?

SECTION THREE

INTENTIONAL TEACHING of Science Content Through Engineering Practices

In the text box provided below the open ended question please write your response providing as much detail as possible.

What instructional strategies should teacher educators use when preparing K-12 pre-service science teachers to ***intentionally teach targeted science content*** through engineering practices to (strategies used to prepare them to intentional teach science content through that practice)?

Please provide any additional comments you may want to share.

Thank you,

Jim Carlson

Appendix G

Round 2 Questionnaire

Email

Dear Delphi Panel Members,

Thank you for agreeing to participate in this study and for having provided responses to the Round I questionnaire. As you will recall, the purpose of this study is to characterize a methodological framework for preparing science educators to implement design-based engineering practices to intentionally teach targeted science content. Results from the Round I questionnaire have been summarized and combined into the Round II Questionnaire.

Below is a link to the Round II Questionnaire of this Delphi study. It should take 30-40 minutes to complete. Please click on the link below or paste it into your browser and complete the questionnaire by Monday, June 27, 2016. If you have any questions you can contact me at carlsonj@vt.edu. In approximately two weeks you should expect to will receive instructions for Round III of this study.

Link to Round 2 Questionnaire: http://goo.gl/forms/JBkW3EUBq5

*Please note once you begin you must continue to the last page of the questionnaire and submit your responses. If you exit without submitting your questionnaire your responses will not be recorded. If you need to stop during the questionnaire please continue to the end of the questionnaire and submit your answers. You will then be provided a URL that will allow you to go back and edit your responses.

As a reminder all responses to this Delphi study will remain anonymous to other panel members and you may choose to withdraw from this study at any time without any negative consequences.

Sincerely,

James S. Carlson
Ph.D. Candidate
Integrative STEM Education
Department of Teaching and Learning
Virginia Tech
52 Old Ponsett Road
Haddam, CT 06438
ph. 860.554.5398
carlsonj@vt.edu

Round 2 Incentive Email 2nd Request

Dear Panel Members,

I want to take this opportunity to thank all of you for your time and energy thus far to help me characterize a methodological framework for preparing science educators to implement design-based engineering practices. From the feedback I received so far, I understand that my second round questionnaire is taking significantly more time to complete and therefore calls for more effort on your part. I apologize for the length of the questionnaire, but it reflects the entire body of panelists' responses identifying specifically targeted items suggested for inclusion in the framework.

Currently I have received a few completed Round II questionnaires, but am well short of what I need in order to complete the second round and move forward with the research. To encourage greater participation and show my sincere appreciation for your time and effort, I would like to offer some incentives for completing Round II and III questionnaires. Upon completion of the last questionnaire which will be sent out in Round III, your name will be entered in a drawing to win one of three amazing prizes!!!* The pool of panelists is small, and therefore the odds of being selected for one of the three prizes are relatively good.

1st Prize: $250 Southwest Airline Gift Card

2nd Prize: Amazon Echo

3rd Prize: $100 Amazon Gift Card

If you haven't completed your Round II questionnaire yet, please do so before Friday, July 22nd. The success of this study is completely dependent on your responses. That said, I hope these incentives will encourage you to complete the entire questionnaire in the very near future.

Link to Round II Questionnaire: http://goo.gl/forms/FY6VBLQSt5cR3RUo2

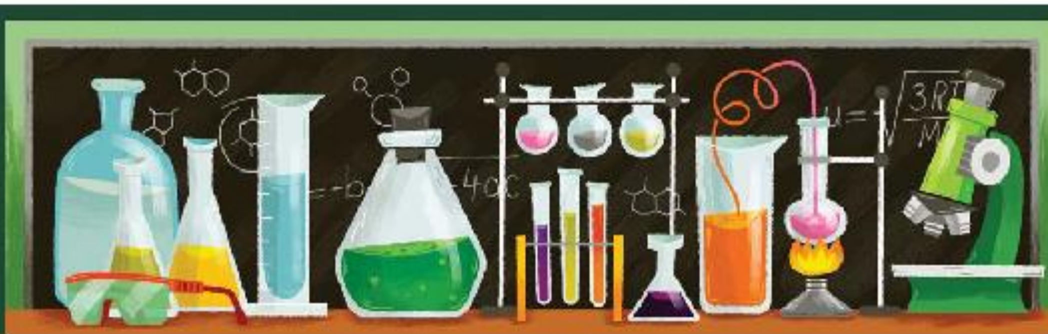
If you have any questions please don't hesitate to contact me.

Sincerely,

James Carlson

*Limit of one prize per person.

Round 2 Questionnaire



Round 2 Questionnaire

Consent Form

I fully understand the nature of this commitment and intend to do my best to fulfill all of the obligations associated with this study. I also understand that I may withdraw from this study at any time without consequences of any kind. Please type your name in the bellow to accept this agreement.

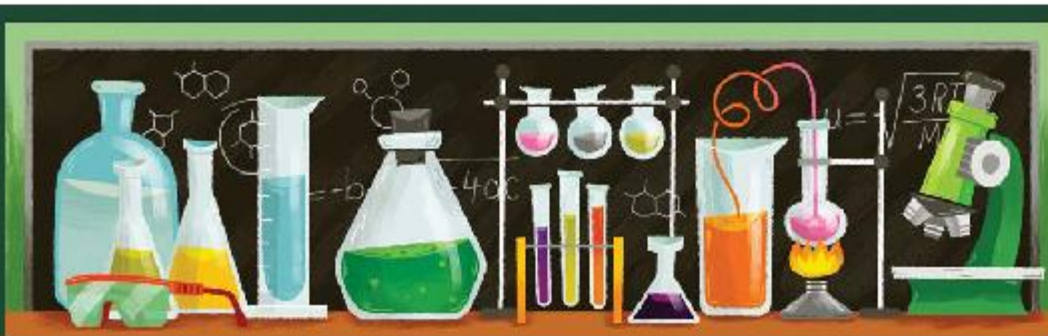
Electronic Signature

First Name

Last Name

Questions About the Study Please Contact:

James S. Carlson
Ph.D. Student
Integrative STEM Education
Department of Teaching and Learning
Virginia Tech
52 Old Ponsett Road
Haddam, CT 06438
ph. 860.554.5398
carlsonj@vt.edu



Round 2 Questionnaire

Round 2 Instructions

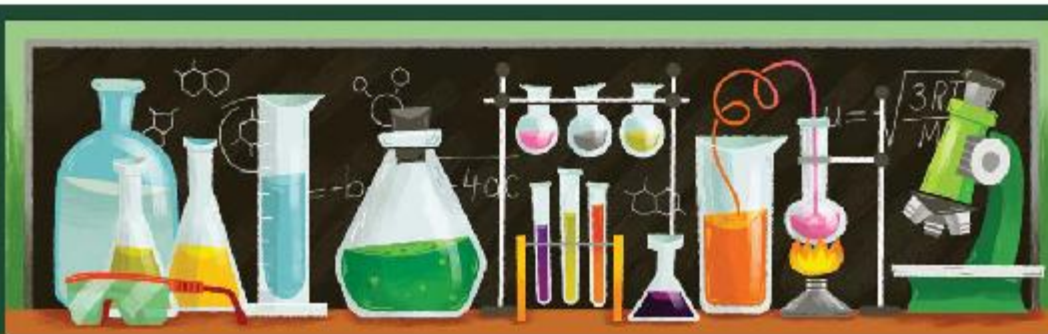
This Round II Questionnaire is separated into the following three sections:

Section One – ***NGSS Practice 1: DEFINING Engineering PROBLEMS***
Section Two – ***NGSS Practice 6: DESIGNING Engineering SOLUTIONS***
Section Three – ***INTENTIONAL TEACHING of Science Content.***

Each of the panel members statements from Round 1 were analyzed to identify those that were identical and those unique. All statements considered to be identical were merged and counted as a single statement. These statements were then summarized.

In each of the following sections you will find these summarized statements, please carefully follow the instructions provided in each section for how you are to rate these statements.

« Back   Continue »



Round 2 Questionnaire

SECTION ONE

NGSS PRACTICE 1: *DEFINING Engineering PROBLEMS*

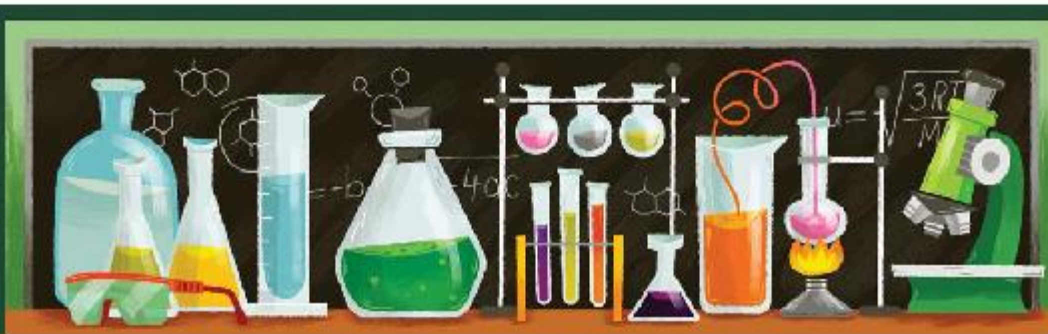
Practice 1 of the NGSS stipulates that all K-12 science teachers should have the ability to define engineering problems as a practice they would teach and that all their students should be able to do. Recall that the Round I questionnaire asked two questions regarding NGSS Practice 1, one which addressed minimum teacher competencies and the other teacher preparation strategies.

On the following pages each question will be presented, followed by panel member responses. Below each response you will find an 11-Point scale, with 0 being strongly disagree and 10 being strongly agree. Using that scale you are to rate "your level of agreement" regarding the response. Simply click the radio button for the level that best reflects your opinion concerning the content of the response.

Following each of the statements you will find a text box is available for you to provide the reason/justification for your rating. Please provide this information as it serves an important role in subsequent rounds.

It is suggested that you read through the entire questionnaire before you begin rating the responses because some of the responses may have similar descriptions, but differ slightly.

« Back   Continue »



Round 2 Questionnaire

Section One

Question 1: COMPETENCIES QUESTION

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Question stem:

To demonstrate competency in ***DEFINING ENGINEERING PROBLEMS*** all K-12 pre-service teachers must be able to:

I. do hands on investigations to gather insights/information about engineering design challenges.

	0	1	2	3	4	5	6	7	8	9	10	
Strongly Disagree	○	○	○	○	○	○	○	○	○	○	○	Strongly Agree

Comment: Provide a brief reason/justification for your rating

2. explain engineering problems.

	0	1	2	3	4	5	6	7	8	9	10	
Strongly Disagree	○	○	○	○	○	○	○	○	○	○	○	Strongly Agree

Comment: Provide a brief reason/justification for your rating

3. identify multiple solutions to an engineering problem.

	0	1	2	3	4	5	6	7	8	9	10	
Strongly Disagree	○	○	○	○	○	○	○	○	○	○	○	Strongly Agree

Comment: Provide a brief reason/justification for your rating

4. research solutions to an engineering problem.

	0	1	2	3	4	5	6	7	8	9	10	
Strongly Disagree	○	○	○	○	○	○	○	○	○	○	○	Strongly Agree

Note. Continued below is a listing of only the questions. Graphics have been removed for readability.

Question stem: To demonstrate competency in *DEFINING ENNEERING PROBLEMS* all K-12 pre-service teachers must be able to:

A-5	explain engineering design problems in written form.
A-6	ask questions about engineering problems.
A-7	analyze STEM learning experiences regarding their focus on state curriculum standards.
A-8	apply Disciplinary Core Ideas.
A-9	demonstrate logical thinking when planning engineering tasks.
A-10	apply STEM pedagogical concepts, in design, technology and engineering education in STEM focused curricular models.
A-11	assess student understanding of inquiry, scientific processes and computational thinking through observations.
A-12	break engineering problems into smaller parts.
A-13	read engineering design problems for contextual clues.
A-14	define what computational thinking is.
A-15	define the constraints of engineering problems.
A-16	define a engineering problem.
A-17	define a science problem.
A-18	define the meaning of scientific inquiry.
A-19	demonstrate that technology is about modifying the natural world to meet human needs and wants.
A-20	define the meaning of engineering.
A-21	define what engineering is.
A-22	describe the basic steps of the engineering design process.
A-23	design instructional environments that accommodate inquiry-based pedagogies.
A-24	prepare teaching materials that provide contextual clues to engineering based problems.
A-25	determine which scientific questions may be addressed using engineering practices.
A-26	develop solutions to engineering problems.
A-27	differentiate between the practices of scientific inquiry and engineering design.

Question stem: To demonstrate competency in *DEFINING ENNEERING PROBLEMS* all K-12 pre-service teachers must be able to:

A-28	embed engineering activities into science content.
A-29	explain how the engineering process differs from the scientific method.
A-30	explain the meaning of engineering.
A-31	explain what engineering is.
A-32	facilitate student development in engineering design practices.
A-33	focus on practical engineering solutions to a problem.
A-34	work in small cooperative groups.
A-35	identify the concepts that occur in economics, engineering, human impact, safety, and technology and how they related to technology and engineering education.
A-36	identify the constraints on an engineering problem.
A-37	identify engineering design criteria.
A-38	identify engineering design performances.
A-39	identify the critical content and skills objectives of an educational standard in order to intentionally focus the development of engineering problems during a lesson.
A-40	identify engineering problems that require engineering solutions.
A-41	identify grade and age appropriate engineering content.
A-42	identify interdisciplinary connections to engineering.
A-43	identify how personal beliefs influence design.
A-44	identify other practices of academia, such as economics, human impact, and safety, and relate them to practices of engineering and science.
A-45	identify the technology and engineering concepts of each in the STEM fields.
A-46	identify the technology and engineering practices in each of the STEM fields.
A-47	implement design based strategies in technology and engineering and STEM focused curricular applications.
A-48	implement design based instructional methods in technology and engineering and STEM focused curricular applications.
A-49	implement STEM learning experiences according to state standards.
A-50	implement technology and engineering instructional methods.
A-51	implement technology and engineering instructional strategies.
A-52	make scientific observations to formulate multiple ideas, questions and problems related to those observations.

Question stem: To demonstrate competency in *DEFINING ENNEERING PROBLEMS* all K-12 pre-service teachers must be able to:

A-53	meet the institutional goals of sustainability.
A-54	model the engineering process to demonstrate that this process differs from the scientific process.
A-55	model ethical research procedures.
A-56	analyze engineering problems.
A-57	identify engineering problems.
A-58	take risk when solving engineering problems.
A-59	provide meaningful examples of engineering and engineering problems that will be understood by their students.
A-60	select grade and age appropriate engineering design scenarios and challenges that enable the application of scientific concepts.
A-61	define a problem that can be solved using technical means.
A-62	use the engineering design process to solve a problem.
A-63	understand computational thinking.
A-64	understand the concepts of grade and age appropriate engineering activities.
A-65	identify the desired performances, criteria and constraints of an engineering design challenge.
A-66	understand the design constraints of an engineering problem.
A-67	understand the design tradeoffs of an engineering problem.
A-68	understand Disciplinary Core Ideas.
A-69	understand engineering as a process.
A-70	understand engineering problems.
A-71	understand the Framework for K-12 Science Education.
A-72	understand how to teach engineering practices.
A-73	understand how to teach science content.
A-74	understand the shifts in NGSS as indicated in the Framework of K-12 Science Education.
A-75	understand scientific inquiry.
A-76	understand the vocation of engineering.
A-77	utilize educational standards in the development of engineering problems.
A-78	utilize an iterative design process to solve societal problems.
A-79	utilize real world examples when solving engineering design problems.
A-80	utilize engineering tools and instruments.

SECTION ONE

QUESTION 2: STRATEGIES QUESTION

What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DEFINING engineering PROBLEMS*** (strategies used to prepare them to teach that practice)?

Question stem: When preparing K-12 pre-service teachers to DEFINE ENGINEERING PROBLEMS teacher educators should engage their students in:

B-1	administering problem-based engineering activities.
B-2	analyzing engineering case studies.
B-3	developing problem-based learning activities and lessons that require students to apply engineering concepts.
B-4	applying engineering practices.
B-5	developing problem-based learning activities and lessons that require students to apply scientific concepts.
B-6	developing problem-based learning activities and lessons that require students to apply scientific practices.
B-7	creating authentic engineering activities.
B-8	creating authentic science activities.
B-9	brainstorming engineering activities.
B-10	designing and building a technical device that solves an engineering problem.
B-11	collaborative critique of engineering design resources.
B-12	collaborative engineering design activities.
B-13	collaborative engineering learning activities.
B-14	collaboratively aligning science and engineering lessons to the NGSS.
B-15	comparing and contrasting the science approach to the engineering approach in order to solve the same problem.
B-16	computational thinking science activities.
B-17	conducting curriculum inventories to identify potential areas to utilize engineering design.
B-18	contextualizing scientific phenomena to determine whether it involves a problem of engineering design.
B-19	cooperative learning activities.
B-20	defining engineering problems.
B-21	defining scientific questions.
B-22	demonstrating the difference between scientific inquiry and engineering design.

Question stem: When preparing K-12 pre-service teachers to DEFINE ENGINEERING PROBLEMS teacher educators should engage their students in:

B-23	demonstrations of laboratory practices used in technology and engineering.
B-24	demonstrating ethical research procedures.
B-25	describing the purpose of integrative STEM education.
B-26	design-based lessons to modeling the practices identified in the NGSS.
B-27	design-based pedagogical approaches intentionally to teach the content and practices of science and mathematics education through the content and practices of technology/engineering education.
B-28	designing age and grade appropriate inquiry/design based instructional models.
B-29	designing hands-on problem solving lessons in science and engineering.
B-30	designing technical devices to solve engineering problems.
B-31	determining to involve engineering design in science problems.
B-32	developing knowledge of technical skills.
B-33	developing technological problem statements.
B-34	developing problem-based learning activities that requires students to apply both scientific and engineering concepts and practices.
B-35	development of engineering design challenges.
B-36	differentiating between scientific inquiry and engineering design.
B-37	differentiating problem based learning and project based learning.
B-38	discussing engineering case studies.
B-39	discussing concepts of the NGSS and how engineering design practices should be embedded within the curriculum.
B-40	peer discussions on the conceptual shifts of K-12 Science Framework.
B-41	distinguishing science problems that require engineering solutions.
B-42	documenting engineering design solutions.
B-43	embracing ambiguity and guiding students towards a understanding of a problem.
B-44	hands-on engineering design activities.
B-45	hands-on problem solving activities.
B-46	identifying the technological/engineering constraints of engineering problem.
B-47	identifying the technological/engineering criteria of an engineering problem.
B-48	identifying technological/engineering problems.
B-49	identifying design constraints due to available materials or class time.

Question stem: When preparing K-12 pre-service teachers to DEFINE ENGINEERING PROBLEMS teacher educators should engage their students in:

B-50	identifying engineering problems.
B-51	identifying science questions.
B-52	identifying the vocation of engineering.
B-53	interdisciplinary STEM teams to solve engineering problems.
B-54	introducing educational resources such as the NGSS.
B-55	isolated scientific phenomena to determine if it involves engineering design problem.
B-56	keeping a journal.
B-57	facilitated science and engineering lessons.
B-58	making connections between science and engineering concepts.
B-59	making connections between science and engineering practices.
B-60	making scientific models.
B-61	modeling the utilization of science materials.
B-62	modeling scientific inquiry practices.
B-63	modeling safe technology and engineering tool use.
B-64	open-ended, multiple solution engineering problems.
B-65	participating in science lessons as students.
B-66	peer evaluations of curriculum focused on the defining of engineering problems.
B-67	practicing project based engineering learning challenges.
B-68	presentations on scientific phenomena.
B-69	presentations using scientific experiences.
B-70	presentations using scientific models.
B-71	problem based engineering activities.
B-72	design based engineering instruction.
B-73	developing engineering prototypes.
B-74	providing feedback to K-12 students.
B-75	reading the K-12 science Framework.
B-76	reflecting on the environmental safety, economical, and human impact constraints of a science problem.
B-77	researching the engineering design processes.
B-78	reviewing engineering case studies.
B-79	scientific inquiry activities.
B-80	teaching mini engineering lessons to their peers

Question stem: When preparing K-12 pre-service teachers to DEFINE ENGINEERING PROBLEMS teacher educators should engage their students in:

B-81	applying technological/engineering design pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education.
B-82	appropriate instructional strategies to engage students in the engineering design-processes.
B-83	using argumentation skills.
B-84	using case studies.
B-85	using data analysis.
B-86	using data collection.
B-87	using differentiated instruction to teach engineering design.
B-88	using formative assessments to gather evidence of students' learning, provide timely feedback, and adjust daily instruction.
B-89	group discourse.
B-90	using hands on learning experiences in students own discipline (bio, Chemistry, physics).
B-91	using instructional strategies to monitor student progress of engineering design concepts.
B-92	using integrative engineering design based instructional strategies.
B-93	using performance rubrics to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.
B-94	using summative assessments to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.
B-95	concept mapping.
B-96	cooperative learning activities so students can see how teams are vital to the success of an engineering project.
B-97	utilizing engineering design exemplars.
B-98	media presentations of exemplary science and engineering instruction.
B-99	utilizing peer sharing to present findings in an effective manner.
B-100	utilizing peer sharing.
B-101	utilizing science content to work through engineering models.
B-102	writing lessons focusing on modeled pedagogy.

SECTION TWO

NGSS PRACTICE 6: DESIGNING *Engineering* SOLUTIONS

Practice 6 of the NGSS stipulates that all K-12 science teachers should have the ability to design engineering solutions as a practice they would teach and that all their students should be able to do. Recall that the Round I questionnaire asked two questions regarding NGSS Practice 6, one which addressed minimum teacher competencies and the other teacher preparation strategies.

On the following pages each question will be presented, followed by panel member responses. Below each response you will find an 11-point scale, with 0 being strongly ***disagree*** and 10 being strongly ***agree***. Using that scale you are to rate "your level of agreement" regarding the response. Simply click the radio button for the level that best reflects your opinion concerning the content of the response.

Following each of the statements you will find that space has been provided for you to offer the reason/justification for your rating.

It is suggested that you read through the entire questionnaire before you begin rating the responses because some of the responses may have similar descriptions, but differ slightly.

SECTION 2

QUESTION 1: COMPETENCIES QUESTION

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DESIGN engineering SOLUTIONS*** as a practice they would teach students?

Question stem: To demonstrate competency in *DESIGING ENGINEERING SOLUTIONS* all K-12 pre-service teachers must be able to:

A-1 explain science problems in written form.
A-2 analyze engineering design solutions.
A-3 analyze scientific data.
A-4 choose an engineering design solution.
A-5 do hands on engineering prototyping activities.
A-6 identify multiple solutions to an engineering problem.
A-7 design and test engineering prototypes.
A-8 utilize debugging to solve engineering problems.
A-9 utilize feedback to refine engineering prototypes.
A-10 adapt prior engineering design solutions.
A-11 adapt prior technologies.

Question stem: To demonstrate competency in *DESIGING ENGINEERING SOLUTIONS* all K-12 pre-service teachers must be able to:

A-12	add additional content to and engineering problem in an effort to find a solution.
A-13	analyze STEM learning experiences regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.
A-14	apply contextual reading skills.
A-15	apply design, engineering and technology literacy standards in the design and implementation of DTE learning activities.
A-16	demonstrate logical thinking in the design of engineering activities.
A-17	apply STEM pedagogical concepts in design, technology and engineering education in STEM focused curricular models.
A-18	augment engineering problems in an effort to solve it.
A-19	combine elements of engineering problem in an effort to solve it.
A-20	combine techniques of engineering problem in an effort to solve it.
A-21	share engineering design ideas and solutions to reflect on the design work, the processes used and decisions made.
A-22	create engineering models.
A-23	define the meaning of "engineering by design".
A-24	define science content in engineering problems.
A-25	understand technology is about modifying the natural world to meet human needs and wants and engineering applies math and science to create technology.
A-26	demonstrate aesthetic quality in engineering solutions.
A-27	demonstrate the engineering design process.
A-28	describe the science content in an engineering problem.
A-29	design engineering solutions to a science problem.
A-30	differentiate between scientific inquiry and engineering design.
A-31	engage in reflection.
A-32	explain design-based engineering practices.
A-33	explain the science content behind an engineering problem.
A-34	understand idea-generating strategies.
A-35	identify alternative engineering solutions.
A-36	identify alternative uses of engineering materials.
A-37	identify connections between science and engineering.
A-38	identify technological/engineering design constraints.
A-39	identify technological/engineering design criteria.
A-40	identify the engineering design cycle.

Question stem: To demonstrate competency in *DESIGING ENGINEERING SOLUTIONS* all K-12 pre-service teachers must be able to:

A-41	identify grade and age appropriate engineering content.
A-42	identify multiple solutions to solve an engineering problem.
A-43	identify multiple strategies to solve an engineering problem.
A-44	identify the parameters to solve an engineering problem.
A-45	identify resources to solve an engineering problem.
A-46	identify values to solve an engineering problem.
A-47	implement design based engineering instructional methods.
A-48	implement design based engineering instructional strategies.
A-49	implement inquiry-based science pedagogies.
A-50	implement STEM learning experiences regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.
A-51	implement state standards regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.
A-52	incorporate alternative materials to solve engineering problems.
A-53	incorporate alternative techniques to solve engineering problems.
A-54	make informed decisions to solve engineering problems.
A-55	manage student behaviors.
A-56	meet institutional goals of sustainability.
A-57	model a variety of analytical engineering skills.
A-58	model collaborative brainstorming skills.
A-59	model a variety of physical engineering skills.
A-60	model a variety of virtual engineering skills.
A-61	understand the practice of the engineering design process.
A-62	rearrange the elements of an engineering problem.
A-63	reflect on engineering design solutions.
A-64	sketch and complete finished technical drawings.
A-65	support interdisciplinary collaborations.
A-66	take risks when designing a solution.
A-67	test engineering materials.
A-68	understand the approaches to problem solving found in the Standards for Technology Literacy.
A-69	understand the Disciplinary Core Ideas found in NGSS.
A-70	understand engineering as a process to design a solution.
A-71	understand the engineering design process.
A-72	understand engineering design in relation to understanding science.
A-73	understand engineering related problems.
A-74	understand technical writing.

Question stem: To demonstrate competency in *DESIGING ENGINEERING SOLUTIONS* all K-12 pre-service teachers must be able to:

A-75	understand technical components of STEM.
A-76	understand engineering components of STEM.
A-77	understand the utilization of engineering materials.
A-78	understand the vocation of engineering.
A-79	understand the use of models in NGSS and how engineering design models differ from models in science.
A-80	complete computer aided design drawings of proposed solutions.
A-81	utilize engineering design to integrate STEM.
A-82	utilize models to design solutions to engineering tasks.
A-83	create a classroom culture that supports collaboration and appreciates that designs should be tested to the point of failure.
A-84	utilize graphical communications.
A-85	utilize modeling.
A-86	utilize real world engineering examples.
A-87	utilize systems thinking.
A-88	safely utilize technological/ engineering tools, machines and instruments.
A-89	value failures.

SECTION 2

QUESTION 2: STRATEGIES QUESTION

What instructional strategy/strategies should teacher educators use when preparing K-12 pre-service science teachers to teach students ***the practice of DESIGNING engineering SOLUTIONS*** (strategies used to prepare them to teach that practice)?

Question stem: When preparing K-12 pre-service teachers to DESIGN ENGINEERING SOLUTIONS teacher educators should engage their students in:

B-1	applying engineering problems and processes to specific science content.
B-2	authentic engineering problem solving activities.
B-3	brainstorming ideas for engineering solutions.
B-4	building arguments from evidence.
B-5	building technical devices.
B-6	Capstone projects.
B-7	collaborative brainstorming activities.
B-8	Computer Aided Design.
B-9	concurrent engineering activities.

Question stem: When preparing K-12 pre-service teachers to DESIGN ENGINEERING SOLUTIONS teacher educators should engage their students in:

B-10	coping with K-12 student failure.
B-11	courses with breadth and depth in science concepts.
B-12	dealing with K-12 student resistance when there is not a clear path.
B-13	demonstrating the utilization of science materials
B-14	demonstrations.
B-15	demonstrating a structured process for designing engineering solutions.
B-16	describing the basic steps of engineering design process.
B-17	design teams.
B-18	lesson planning.
B-19	developing knowledge of general technical skills.
B-20	developing possible engineering solutions.
B-21	differentiating invention and innovation.
B-22	discussing the concepts of the NGSS and the integration of subjects as well as how the engineering design practices should be embedded within the curriculum.
B-23	documenting engineering design work.
B-24	engineering activities that requiring debugging.
B-25	the engineering design process.
B-26	instruction in the methodology of problem-solving and how it is applied to engineering practices.
B-27	envisioning solutions through the use of sketching, orthographic projection, perspective drawing, CAD drawing, etc.
B-28	evaluating the strengths and weaknesses of an exemplar science and engineering lesson.
B-29	experiencing cooperative learning strategies.
B-30	experiencing hands-on engineering design activities in their own content area.
B-31	experiencing problems that require an engineering-type solution.
B-32	exposure to multiple engineering design methods.
B-33	facilitated lessons.
B-34	group facilitation.
B-35	hands-on engineering design activities.
B-36	hands-on engineering problem solving activities.
B-37	identifying areas of a lesson that can be enriched with engineering design.
B-38	identifying areas of a lesson that can be enriched with STEM connections
B-39	identifying problems experienced by K-12 science students.
B-40	identifying steps of the engineering design process during reflection.

Question stem: When preparing K-12 pre-service teachers to DESIGN ENGINEERING SOLUTIONS teacher educators should engage their students in:

B-41	identifying the strengths and weaknesses of exemplar science and engineering lessons.
B-42	identifying the vocation of engineering.
B-43	incorporating design activities into case study exploration and resolution.
B-44	iterative engineering design activities.
B-45	modeling visualization techniques.
B-46	modeling design based engineering practices.
B-47	modeling safe technology/engineering tool use.
B-48	open-ended, multiple solution problems.
B-49	peer evaluations for the improvement of engineering designs.
B-50	practicing engineering design problems.
B-51	predictive modeling.
B-52	proposing design solutions that consider human and environmental factors.
B-53	reflecting on key scientific concepts identified and conceptual shifts in NGSS.
B-54	representation modeling
B-55	risk taking classroom culture structures.
B-56	age and grade appropriate engineering design activities.
B-57	selecting appropriate technological/engineering resources.
B-58	technical sketching.
B-59	systems thinking.
B-60	technical drawings.
B-61	technical writing.
B-62	testing of engineering design solutions.
B-63	technology/engineering tool use.
B-64	trial and error activities of design production and implementation.
B-65	utilizing appropriate technical/engineering resources.
B-66	collect data based on their solutions to the problem.
B-67	utilizing engineering design to integrate multiple content areas into science.
B-68	utilizing scientific evidence to evaluate solutions to engineering problems.
B-69	utilizing cooperative learning activities so students can see how teams are vital to the success of an engineering project.
B-70	utilizing media presentations to show examples of collaborative work skills in engineering design as well as to present their findings.
B-71	utilizing mini lectures on engineering design concepts.
B-72	utilizing concept mapping.
B-73	utilizing formative assessment for engineering design.

Question stem: When preparing K-12 pre-service teachers to DESIGN ENGINEERING SOLUTIONS teacher educators should engage their students in:

B-74 utilizing peer sharing.
B-75 writing lessons for engineering applications of science content.

SECTION THREE

INTENTIONAL TEACHING of Science Content Through Engineering Practices

Successful implementation of NGSS Practice 1 and Practice 6 necessitates that teachers have an understanding and the ability to implement design-based engineering practices to ***intentionally teach targeted science content***. Recall that the Round I questionnaire asked one question regarding the intentional teaching of targeted science content when engaged in engineering practices.

On the following pages each question will be presented, followed by panel member responses. Below each response you will find an 11-point scale, with 0 being strongly ***disagree*** and 10 being strongly ***agree***. Using that scale you are to rate "your level of agreement" regarding the response. Simply click the radio button for the level that best reflects your opinion concerning the content of the response.

Following each of the statements you will find that space has been provided for you to offer the reason/justification for your rating.

It is suggested that you read through the entire questionnaire before you begin rating the responses because some of the responses may have similar descriptions, but differ slightly.

SECTION 3

QUESTION 1: INTENTIONAL TEACHING QUESTION

What instructional strategies should teacher educators use when preparing K-12 pre-service science teachers to ***intentionally teach targeted science content*** through engineering practices to (strategies used to prepare them to intentional teach science content through that practice)?

Question stem: When preparing K-12 pre-service teachers to *INTENTIONALLY TEACH TARGETED SCIENCE CONTENT* teacher educators should engage their students in:

S-1 analyzing the appropriateness of an engineering design activity.
S-2 analyzing the effectiveness of an engineering design activity.

Question stem: When preparing K-12 pre-service teachers to *INTENTIONALLY TEACH TARGETED SCIENCE CONTENT* teacher educators should engage their students in:

S-3	applying engineering practices to a problem clearly linked to science content.
S-4	approaching engineering as a way of doing.
S-5	approaching engineering as a way of thinking.
S-6	authentic science problem solving activities.
S-7	the NGSS to identify how the design process can be used to teach specific content by combining different standards and benchmarks.
S-8	content knowledge identified in the NGSS.
S-9	contrasting processes used by scientists with those used by professionals in other disciplines.
S-10	cooperative learning.
S-11	creating tools and instrumentation for collecting scientific data.
S-12	critiquing engineering lessons to identify science content.
S-13	critiquing science lessons to identify engineering content.
S-14	experiencing exemplary engineering design activities.
S-15	designing engineering solutions.
S-16	designing investigative science solutions.
S-17	designing science lesson plans, teaching and then reflecting on these lessons.
S-18	determining engineering problems.
S-19	determining science questions.
S-20	developing age and grade appropriate engineering design challenges.
S-21	developing situational awareness of malfunctioning systems in operation to determine what is not working correctly.
S-22	developing standards-based engineering activities.
S-23	developing standards-based engineering experiences.
S-24	discussing STEM concepts associated with the activity or experience.
S-25	distinguishing between engineering and science concepts.
S-26	establishing collaboration between science teacher educators and technology and engineering teacher educators.
S-27	examining the engineering design process as a content method.
S-28	examining the engineering design process as a pedagogical method.
S-29	exhibiting techniques for questioning different phenomena.
S-30	exposing student teachers to scientific phenomena.
S-31	focusing on a limited number of engineering concepts.
S-32	focusing on broad themes rather than atomistic competencies.

Question stem: When preparing K-12 pre-service teachers to *INTENTIONALLY TEACH TARGETED SCIENCE CONTENT* teacher educators should engage their students in:

S-33	formative assessment of open ended engineering problems.
S-34	framing engineering design activities as a tool for getting to the science content objectives of the NGSS standard we're addressing.
S-35	hands on/minds on science activities.
S-36	identifying engineering situations that enable the integration of science lessons.
S-37	identifying and discuss cross-disciplinary intersections between science, technology, and engineering education.
S-38	identifying educational objectives.
S-39	the process of identifying key science content.
S-40	identifying STEM concepts associated with the activity or experience.
S-41	implementing age and grade appropriate engineering design challenges.
S-42	inquiry based activities.
S-43	scientific inquiry instruction.
S-44	the use of science rubrics such as the dimensions of success tool to measure student engagement.
S-45	introducing students to technology and engineering organizations such as ITEEA & ASEE.
S-46	introducing targeted science content through guided practice.
S-47	iterative engineering design activities.
S-48	judge spatial relationships, (e.g., visualize how a system operates and mentally rotate system parts to solve problems within a given system.)
S-49	lessons and activities where students are faced with an engineering problem.
S-50	lessons where science content is taught through engineering practices.
S-51	making comparisons, (e.g., what commonalities and differences do systems have?)
S-52	making predictions, (e.g., based on what has been observed, what is known about a specific system, and what is known about related scientific principles, make a prediction about what will happen next.)
S-53	managing group-oriented projects.
S-54	managing open-ended, multiple solution problems.
S-55	short video clips or actual teaching sequences to illustrate how a master teacher uses the design activity to teach targeted science content.
S-56	modeling integrating science teaching in engineering design.
S-57	participating in science lessons as K-12 students.

Question stem: When preparing K-12 pre-service teachers to *INTENTIONALLY TEACH TARGETED SCIENCE CONTENT* teacher educators should engage their students in:

S-58	problem based learning activities.
S-59	providing engineering is elementary and other curriculum resources.
S-60	providing resources such as websites, handouts, expert guest speakers, ect.
S-61	recognizing probable outcomes, (e.g., how will the system react to a specific action?)
S-62	the same things used to teach technology and engineering teachers.
S-63	science-specific pedagogical approaches.
S-64	scientific argumentation.
S-65	summative assessments.
S-66	teaching sequences utilizing design activities.
S-67	technological problem solving techniques.
S-68	understanding cause and effect relationships.
S-69	understanding how engineering and science concepts function.
S-70	understanding inquiry.
S-71	understanding science concepts.
S-72	understanding STEM content learning.
S-73	understanding STEM engagement.
S-74	understanding the concepts of engineering design as in described in the NGSS.
S-75	utilizing continuous assessment.
S-76	utilizing professional journals to explore teaching pedagogies
S-77	utilizing science to solve engineering problems.
S-78	utilizing STEM to solve social problems.
S-79	utilizing the engineering design process in solving an engineering/technology problem.
S-80	utilizing the pedagogical approach of modeling science curriculum.
S-81	utilizing the pedagogical approach of scientific inquiry.
S-82	utilizing the scientific method in solving a engineering/technology problem.

Appendix H

Round 3 Questionnaire

Dear Delphi Panel Member,

Thank you for your continued participation in this study and responses to the Round II questionnaire. The purpose of this study is to characterize a methodological framework for preparing science educators to implement design-based engineering practices to intentionally teach the application of science content. Results from the Round II questionnaire have been summarized and combined into this Round III Questionnaire.

The Round III questionnaire presents only the items where the panel did not reach consensus during Round II. Below is a link to the Round III questionnaire and is designed specifically for you. In this round, you will be re-rating 19 *NGSS Practice 1* competences, 26 *NGSS Practice 1* strategies, 18 *NGSS Practice 6* competences, 11 *NGSS Practice 6* strategies and 13 instructional strategies.

Round III contains a much smaller set of items and should take you much less time to complete. Before making your new selection, you should consider the group response, along with the reason given by the other panel members, and then select your response. You will be asked to provide a brief reason/justification for why you kept your original rating or chose to change. **Please click on the link below and complete the questionnaire by Monday, October 31, 2016.** If you have any questions you can contact me at carlsonj@vt.edu

Link to Round III Questionnaire: https://goo.gl/forms/t7dfPHxanz2niFyb2

***Please note:** once you begin, you must continue to the last page of the questionnaire and submit your responses. If you exit without submitting your questionnaire, your responses will not be recorded. As a reminder all responses to this Delphi study will remain anonymous to other panel members and you may choose to withdraw from this study at any time without any negative consequences.

I understand it is difficult to find time in your busy lives to participate in such endeavor. Because of your experience and expertise in preparing educators to implement design-based engineering practices in the K-12 classroom, you are critical to this research. I anticipate this to be the last round of my study. Please, let me take this opportunity to express my gratitude and thank you for your time and continued participation. Don't forget upon completion of the all of the questionnaires your name will be entered in a drawing to win one of the following prizes.

1st Prize: $250 Southwest Airline Gift Card
2nd Prize: Amazon Echo
3rd Prize: $100 Amazon Gift Card

I will be contacting the winners of the drawing after I receive all of the questionnaires. If I ever can be assistance please don't hesitate to contact me.

Sincerely,
James S. Carlson

Round 3 Questionnaire

Consent Form

I fully understand the nature of this commitment and intend to do my best to fulfill all of the obligations associated with this study. I also understand that I may withdraw from this study at any time without consequences of any kind. Please type your name in the bellow to accept this agreement.

Electronic Signature

First Name

Last Name

Questions About the Study Please Contact:

James S. Carlson
Ph.D. Candidate
Integrative STEM Education
Department of Teaching and Learning
Virginia Tech
52 Old Ponsett Road
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Should you have any questions or concerns about the study& rsquo;s conduct or your rights as a research subject, you may contact the VT IRB Chair, Dr. David M. Moore at mooredd@vt.edu or (540) 231-4991.

Continue »

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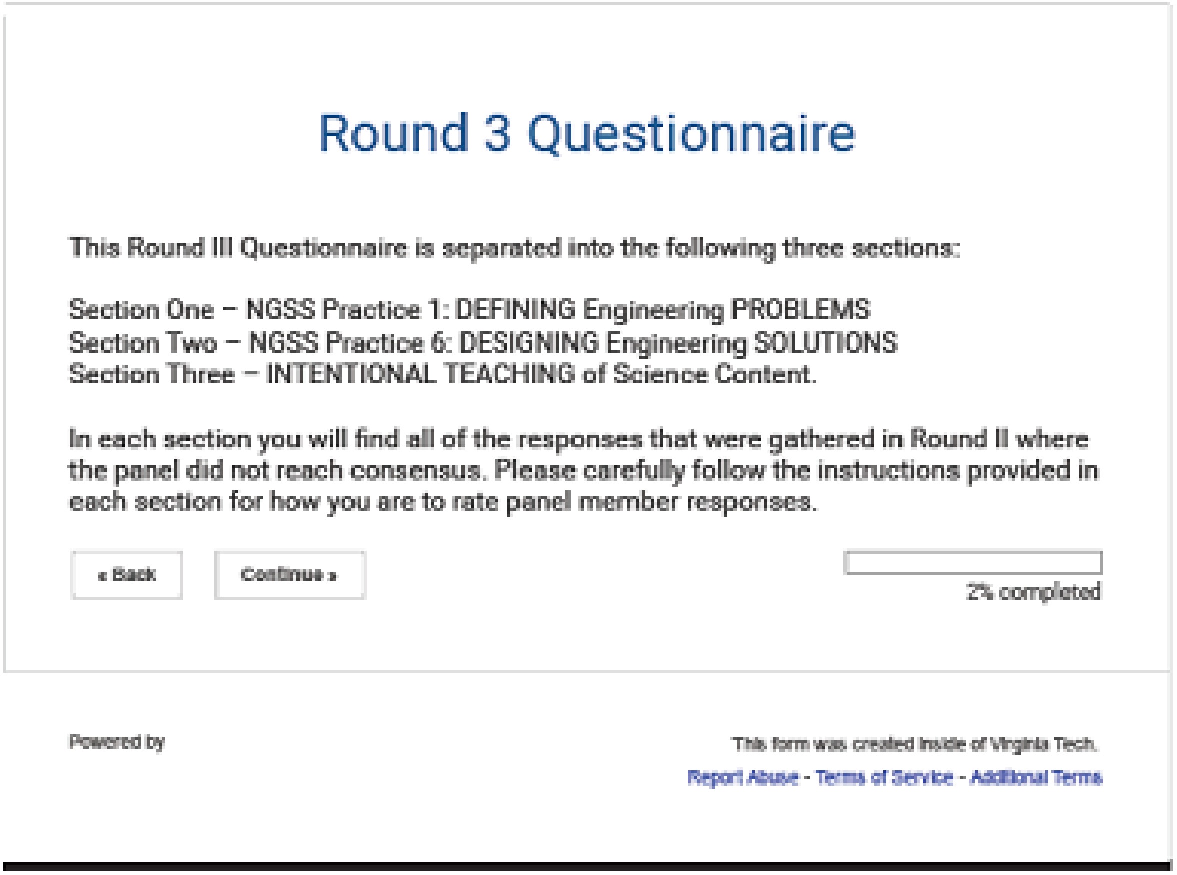

Round 3 Questionnaire

This Round III Questionnaire is separated into the following three sections:

Section One – NGSS Practice 1: DEFINING Engineering PROBLEMS
Section Two – NGSS Practice 6: DESIGNING Engineering SOLUTIONS
Section Three – INTENTIONAL TEACHING of Science Content.

In each section you will find all of the responses that were gathered in Round II where the panel did not reach consensus. Please carefully follow the instructions provided in each section for how you are to rate panel member responses.

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Round 3 Questionnaire

SECTION ONE

NGSS PRACTICE 1: DEFINING Engineering PROBLEMS

Practice 1 of the NGSS stipulates that all K-12 science teachers should have the ability to define engineering problems as a practice they would teach and that all their students should be able to do. Recall that the Round I questionnaire asked two questions regarding NGSS Practice 1, one which addressed minimum teacher competencies and the other teacher preparation strategies. Please keep this in mind when completing this section.

Directions

Presented on the following pages are those items where panelists did not reach consensus. As illustrated in the example below, panelists' ratings of the item are then displayed within the 11-point scale, with yellow boxes used to indicate the Mode(s). A blue arrow is used to indicate your rating of the item.

Example of Rating Scale

The Bimodal rating for this item is: 3, 10

The most commonly chosen rating/ratings are highlighted in yellow.

Strongly Disagree										Strongly Agree
0	1	2	3	4	5	6	7	8	9	10
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Your Original Rating is 1 and the blue arrow represents your position among the panelists for this item.

Listed beneath the ratings are the comments panelists provided regarding their opinion of the item. While reviewing these comments you are asked to reflect on your position relative to the other panelists. After reviewing the comments, reconsider your response and then re-rate the item, regardless whether you rate it the same or differently. Once re-rated, please provide a brief reason for your decision.

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3% completed

Round 3 Questionnaire

Section One: COMPETENCIES QUESTION

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Response A-1: Do hands on investigations to gather insights/information about engineering design challenges.

The Bimodal rating for this item is: 3, 10

The most commonly chosen rating/ratings are highlighted in yellow.

Strongly Disagree										Strongly Agree
0	1	2	3	4	5	6	7	8	9	10
0	1	1	5	0	1	0	1	4	2	[illegible]

Your Original Rating is 1 and the blue arrow represents your position among the panelists for this item.

Panelist Comments: Please review each comment and reflect on your position shown above relative to the other panelist.

Defining the problem does not require hands on investigation. Teacher can learn to define engineering problems through discussion and research.

The hands on activity gives an opportunity to demonstrate and reinforce engineering design issues.

Doing hands on work helps to helps students understand how things work and also serves to motivate them.

Need to engage in the practice to be able to define its components

Round 3 Questionnaire

Section One: COMPETENCIES QUESTION

<u>What minimal set of competencies</u> must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Response A-2: Explain engineering problems.

The Modal rating for this item is: 10

The most commonly chosen rating/ratings are highlighted in yellow.

Strongly Disagree										Strongly Agree
0	1	2	3	4	5	6	7	8	9	10
1	1	[illegible]	1	[illegible]	[illegible]	[illegible]	1	2	1	[illegible]

Your Original Rating is 1 and the blue arrow represents your position among the panelists for this item.

Panel Member Comments: rate your response either the same or differently based on other panelists comments listed below.

Explaining the problem does not require hands on investigation. Teachers can learn to explain design problems through research, discussion, graphic, and written means.

Students must be provided with the 'attack skills' necessary to understand the process of problem solving as it relates to the design process.

It is important to be able to articulate and clarify the nature of engineering problems.

Not sure what this means–are students explaining how to do a problem or explaining what a problem might look like?

I don't know what it means to "explain engineering problems." Is it different than

Round 3 Questionnaire

Section One: COMPETENCIES QUESTION

What minimal set of competencies must all K-12 pre-service science teachers possess (know and do) in order to ***adequately DEFINE engineering PROBLEMS*** as a practice they would teach students?

Response A-5: Explain engineering design problems in written form.

The Modal rating for this item is: 9

The most commonly chosen rating/ratings are highlighted in yellow.

Strongly Disagree										Strongly Agree
0	1	2	3	4	5	6	7	8	9	10
1	0	0	0	2	2	0	0	2	3	2

Your Original Rating is 4 and the blue arrow represents your position among the panelists for this item.

Panel Member Comments: rate your response either the same or differently based on other panelists comments listed below.

To explain a design problem in writing, what is needed is an understanding of the design criteria and constraints and how the solution is to be assessed.

Very helpful as this improves writing skills as well as developed students abilities to logically explain the work they've done.

It's important to communicate about engineering problems but there are multiple channels of communication, not just written.

Good to make sure students can do this, but can define without writing it down.

Note. Continued below is a listing of only the questions. Graphics have been removed for readability. Each panel member received an individualized Round 3 Questionnaire.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

A-1	do hands on investigations to gather insights/information about engineering design challenges.
A-2	explain engineering problems.
A-5	explain engineering design problems in written form.
A-10	apply STEM pedagogical concepts, in design, technology and engineering education in STEM focused curricular models.
A-11	assess student understanding of inquiry, scientific processes and computational thinking through observations.
A-14	define what computational thinking is.
A-17	define a science problem.
A-23	design instructional environments that accommodate inquiry-based pedagogies.
A-32	facilitate student development in engineering design practices.
A-34	work in small cooperative groups.
A-40	identify engineering problems that require engineering solutions.
A-48	implement design based instructional methods in technology and engineering and STEM focused curricular applications.
A-50	implement technology and engineering instructional methods.
A-53	meet the institutional goals of sustainability.
A-55	model ethical research procedures.
A-63	understand computational thinking.
A-70	understand engineering problems.
A-71	understand the Framework for K-12 Science Education.
A-73	understand how to teach science content.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

B-8	creating authentic science activities.
B-11	collaborative critique of engineering design resources.
B-13	collaborative engineering learning activities.
B-19	cooperative learning activities.
B-24	demonstrating ethical research procedures.
B-25	describing the purpose of integrative STEM education.
B-27	design-based pedagogical approaches intentionally to teach the content and practices of science and mathematics education through the content and practices of technology/engineering education.
B-30	designing technical devices to solve engineering problems.
B-32	developing knowledge of technical skills.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

B-37	differentiating problem based learning and project based learning.
B-52	identifying the vocation of engineering.
B-56	keeping a journal.
B-60	making scientific models.
B-61	modeling the utilization of science materials.
B-66	peer evaluations of curriculum focused on the defining of engineering problems.
B-80	teaching mini engineering lessons to their peers
B-85	using data analysis.
B-87	using differentiated instruction to teach engineering design.
B-89	group discourse.
B-90	using hands on learning experiences in students own discipline (bio, Chemistry, physics).
B-91	using instructional strategies to monitor student progress of engineering design concepts.
B-94	using summative assessments to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.
B-95	concept mapping.
B-96	cooperative learning activities so students can see how teams are vital to the success of an engineering project.
B-100	utilizing peer sharing.
B-101	utilizing science content to work through engineering models.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

A-1	explain science problems in written form.
A-4	choose an engineering design solution.
A-8	utilize debugging to solve engineering problems.
A-14	apply contextual reading skills.
A-15	apply design, engineering and technology literacy standards in the design and implementation of DTE learning activities.
A-18	augment engineering problems in an effort to solve it.
A-19	combine elements of engineering problem in an effort to solve it.
A-20	combine techniques of engineering problem in an effort to solve it.
A-34	understand idea-generating strategies.
A-46	identify values to solve an engineering problem.
B-49	implement inquiry-based science pedagogies.
A-55	manage student behaviors.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

A-56	meet institutional goals of sustainability.
A-58	model collaborative brainstorming skills.
A-60	model a variety of virtual engineering skills.
A-64	sketch and complete finished technical drawings.
A-65	support interdisciplinary collaborations.
A-74	understand technical writing.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

B-4	building arguments from evidence.
B-5	building technical devices.
B-8	Computer Aided Design.
B-18	lesson planning.
B-33	facilitated lessons.
B-45	modeling visualization techniques.
B-53	reflecting on key scientific concepts identified and conceptual shifts in NGSS.
B-54	representation modeling
B-60	technical drawings.
B-70	utilizing media presentations to show examples of collaborative work skills in engineering design as well as to present their findings.
B-72	utilizing concept mapping.

Section 3. Question 1S. Instructional Strategies (Sec3-Q STRATEGY)

S-4	approaching engineering as a way of doing.
S-10	cooperative learning.
S-27	examining the engineering design process as a content method.
S-31	focusing on a limited number of engineering concepts.
S-43	scientific inquiry instruction.
S-45	introducing students to technology and engineering organizations such as ITEEA & ASEE.
S-59	providing engineering is elementary and other curriculum resources.
S-68	understanding cause and effect relationships.
S-70	understanding inquiry.
S-73	understanding STEM engagement.
S-76	Utilizing professional journals to explore teaching pedagogies.

Section 3. Question 1S. Instructional Strategies (Sec3-Q STRATEGY)

S-79	utilizing the engineering design process in solving an engineering/technology problem.
S-82	utilizing the scientific method in solving a engineering/technology problem.

Appendix I

Unedited Statements from Round 1 Questionnaire

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Panel Member 1 Technology

Identify and clarify the problem, ask questions, identify the constraints, carefully analyze the problem and break it into small parts, and determine what exactly needs to be done.

Panel Member 2 Technology

1. must understand the 'engineering process'
2. determine the 'problem'
3. determine what do students 'need to know' to solve the problem
4. develop possible solutions based on their research
5. work in small groups in a cooperative manner

Panel Member 3 Technology

1. They must have a clear understanding and knowledge of the "T&E" components of STEM. At a minimum, they must know technology is about modifying the natural world to meet human needs and wants and engineering applies math and science to create technology.

2. They must know the engineering design process is used in engineering and technology to solve open-ended real-world problems. Although there are many variations, they should be able to describe the basic steps in the engineering design process.

3. They should be able to identify the educational standards that are used in each of the STEM fields.

4. Given a matrix listing the STEM areas, pre-service teachers should be able to identify concepts and practices that occur in each of the areas, especially in those practices and content related to technology and engineering education.

Panel Member 4 Technology

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Teachers must be able to situate problems within an authentic real-world context.
Teachers must be able to identify restrictions or constraints for design challenges.
Teachers must be able to define engineering problems as design challenges that can be solved.

Panel Member 5 Science

In order to define engineering problems as a practice they would teach students, K-12 pre-service science teachers must be able to:

1. Distinguish the difference between science questions and engineering problems.
2. Identify the critical content and skills objectives of a standard in order to intentionally focus the development of engineering problems during a lesson.
3. Make scientific observations of phenomenon and formulate multiple ideas, questions and problems related to those observations.
4. Determine which scientific questions may be addressed using engineering practices.
5. Articulate engineering problems in a way that implies knowledge of engineering practices.
6. Identify real world contexts that may be used as context for engineering applications of scientific principles.

Panel Member 6 Technology

1. Understanding of how engineering is different from science.
2. Understanding that engineering is both a technological process as well as a professional discipline.
3. The ability to think logically.
4. Recognize that there are several engineering fields that focus on specific issues.
5. Identify what general education aspects of engineering are appropriate for K-12 students.
6. They must sacrifice some of their science preparation for engineering courses so that they would have some of the pre-requisite skills, like working with testing equipment; general tools and machines, and so forth.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Panel Member 7 Technology

1. Understand the engineering design process and various models of the engineering design process.
2. Understand the difference between engineering design and scientific inquiry.
3. Have gone through and experienced a true engineering design based problem before.

Panel Member 8 Science

Teachers must be able to understand and define inquiry, scientific processes and computational thinking. They should be able to make observations and assess student understanding based on these concepts as well.

Panel Member 9 Science

1. Read for contextual clues.
2. Prepare teaching materials that provide contextual clues to engineering based problems.
3. Identify student level of reading comprehension.

Panel Member 10 Science

Teachers must be able to identify what counts as an engineering problem (i.e., a problem can be solved using accessible material and equipment), explain to students what makes a problem an engineering problem, and construct opportunities that allow students to take risks and explore multiple trials in an attempt to identify possible paths to solutions.

Panel Member 11 Technology

Be able to explain or define what engineering is and what engineering means

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Be able to provide examples of engineering and engineering problems that will be meaningful to and understood by their students

Understand the concepts of parameters, constraints, and specifications, and be able to explain these in age-appropriate ways to students

Select engineering design scenarios or challenges purposefully, with the goal of selecting those that enable application of scientific concepts germane to the grade level curriculum, and that are within the students' range of capability

Panel Member 12 Science

Have to understand what engineers do in their jobs and the diversity of engineering jobs. They have to know how science and engineers work together and how they are different (knowledge vs application). They should experience content embedded engineering activities, should understand how to teach content as well as engineering practices.

Panel Member 13 Technology

Understand what an engineering problem "is"

Understand the field of engineering and how engineering problems are different from experimental problems.

They should be able to adequately define problems themselves.

Panel Member 14 Technology

PLEASE NOTE THAT THIS COMES FROM A CURRENT NSF PROJECT WHERE WE ARE DEVELOPING TEACHING STANDARDS FOR ENGINEERING DESIGN. DR. DAVID CRISMOND (dcrismond@ccny.cuny.edu) IS OUR LEAD RESEARCHER.

Standard 2. Informed Design Practices
When teaching engineering design, teachers facilitate students’ development of engineering design thinking and practices.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

In doing this, teachers provide students with opportunities to:
2.a Understand Challenge – Understand the design challenge by identifying desired performances, criteria and constraints.
2.b Research & Investigate – Do research and hands-on investigations to gather insights/information about the challenge.

Panel Member 15 Technology

Clearly and succinctly define a problem that can be solved via technical means.
Distinguish the difference between problem statements and their solution.
Solve problems related societal needs utilizing an iterative design/problem solving process.
Identify the impacts some problem solutions may have.

Panel Member 16 Science

1. Understanding of the shifts in the NGSS as indicated in the Framework for K-12 Science Education.
2. Realization that giving students design challenges, (instead of have students define the criteria and the constraints), diminishes students' opportunities to learn and apply their science understandings.
3. Ability to identify situations/scenarios that lend themselves to students defining a problem. Situations should be relevant, observable, specific and apply DCIs in the life, earth and physical sciences. For example, if a lake has dying fish...this is the situation/scenario. Students would need to apply their understanding of the DCIs to define what is causing the fish to die, ie. chemicals, food web? Or if it is too hot in the room, students would need to decide what is causing the discomfort, ie. lack of ventilation, shade, personal preference. Possible solutions will vary depending on how students define the problem,

Panel Member 17 Science

1. The differences and similarities between science and engineering.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

2. Focus of engineering on a practical solution to a problem.
3. Engineering requires science content knowledge but also knowledge of other areas--like economics, human impact, safety.
4. Describe and use a model of the engineering process, and that this process differs from the scientific method.

Panel Member 18 Technology

Understand constraints, tradeoffs, problem definition, personal beliefs and how they influence a design. Being able to write out or explain a problem is paramount. Knowing how to access information that is relevant to the problem; this can be electronic sources as well as human. Knowing how to ask questions.

Panel Member 19 Science

1. Apply Design, Engineering and Technology Literacy Standards content knowledge and skills to the designing and implementation of DTE learning activities.
2. Design instructional environments that that accommodate inquiry-based pedagogies, meet institutional goals of sustainability, are welcoming destinations, and support interdisciplinary collaborations.
3. Implement and analyze STEM learning experiences regarding their focus on State Curriculum Standards for Mathematics, Science, Technology, and Engineering–Grades K-8 (MSDE)
4. Implement Design, Technology and Engineering Education Instructional Methods & Strategies in technology and engineering and STEM focused curricular applications.
5. Apply STEM pedagogical concepts, in Design, Technology and Engineering Education in STEM focused curricular models.

Panel Member 20 Technology

Distinguish problems that require engineering solutions.
Clarify criteria.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Define constraints.
Demonstrate safe use of tools.
Model ethical research procedures.
Communicate a structured process for investigating engineering problems.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Panel Member 1 Technology

Project-based instruction with opportunities to practice defining engineering problems.

Panel Member 2 Technology

1. practice using Problem Based Learning challenges to help determine what engineering practices are appropriate to their topic
2. understand the difference between problem based learning and project based learning
3. the role of the teacher is to be a facilitator - not a lecturer

Panel Member 3 Technology

1. I believe these pre-service teachers should be able to describe the purpose of integrative STEM Education (i.e., "the application of technological/engineering design-based pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education").
2. They should be able to develop an "engineering design challenge" that identifies a technology/engineering type problem to solve, including criteria and constraints associated with that problem.
3. They should learn about keeping and engineering notebook that is used to document the solving of an engineering design problem.
4. They should be able to clearly describe how engineering and science concepts and practices are similar, and different.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

5. They should be able to develop a project-based learning (PBL) activity/lesson that requires student to apply both scientific and engineering concepts and practices.

6. They should be able to give effective classroom and laboratory demonstration on practices used in technology and engineering. This activity will require them to learn basic concepts and practices used in engineering.

Panel Member 4 Technology

Teachers must be able to allow for and encourage open-ended, multiple solution problems.

Teachers must be able to make connections between science and engineering concepts and practices.

Teachers must function as facilitators of student learning.

Panel Member 5 Science

Instructional strategies of a teacher educator should always model the strategies we expect pre-service teachers to use in their future classrooms. Therefore, strategies will include:

1. The use of inquiry practices and modeling to engage students in the scientific process, including both scientific and engineering practices.
2. Engaging students in inquiry and modeling experiences that require them to determine the difference between scientific questions and engineering problems, and how they work together to form a complete understanding of science principles and their application.
3. Engaging students in authentic, active science experiences that force them to consider both isolated and contextualized scientific phenomena and determine whether they involve a problem of engineering or design.
4. Presenting students with scientific phenomena, model or experience and asking them to identify and define both the scientific questions and the engineering problems related to those observations.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Modeling pedagogical practice for pre-service teachers acting as students gives them the perspective of the learner. However, it is equally important to for pre-service teachers to practice acting as the teacher for these approaches as well. Therefore, some strategies for this include:

1. Writing lesson plans that include the pedagogy they engaged in as students above.
2. Peer evaluation of curriculum ideas related to getting students to define engineering problems.
3. Teaching mini-lessons to their peers to try out curriculum ideas related to defining engineering problems.

Panel Member 6 Technology

1. Conceptual Mapping.
2. Lesson planning
3. Hands-on design activities.
4. Hands-on problem solving activities.
5. General technical skills and knowledge

Panel Member 7 Technology

1. Immerse them in a true engineering design problem task so they can experience the engineering design process.
2. Require pre-service teachers to research multiple versions of the engineering design process.
3. Understand and distinctly demonstrate the difference between engineering design and scientific inquiry.

Panel Member 8 Science

Teacher educators should engage pre-service teachers in activities that require them to make models to engage in inquiry, scientific processes, and computational thinking for themselves. Unless they actually do the exercises that they require students to do, pre-service teachers will not fully understand the learning curve and the skills that students need to solve engineering problems and participate in engineering tasks.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Panel Member 9 Science

1. Practice Case Study use in classroom settings.
2. Active Learning Teaching Strategies.
3. Inquiry Based Learning
4. Problem Based Learning

Panel Member 10 Science

Pre-service teachers should experience situations where they are exposed to problems that require an engineering-type solution and those that don't (so that they can tell the difference).

Panel Member 11 Technology

Use (review, analyze, discuss) case studies
Engage pre-service teachers in guided activities involving defining engineering problems
Use interdisciplinary teams of STEM (or beyond) pre-service teachers
Conduct curriculum inventories to identify areas that might lend themselves well to use of engineering design

Panel Member 12 Science

Again, know what engineers do and experience hands on content based engineering design challenge activities in their content area (bio, Chem, physics).

Should learn cooperative learning strategies, group discourse tools and inquiry (data collection and analysis) as well as argumentation skills

Panel Member 13 Technology

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Create practical connections to the student's life experiences through examples of engineered products and how they meet defined problems.

Practice defining problems - new and old problems.

Panel Member 14 Technology

PLEASE NOTE THAT THIS COMES FROM A CURRENT NSF PROJECT WHERE WE ARE DEVELOPING TEACHING STANDARDS FOR ENGINEERING DESIGN. DR. DAVID CRISMOND (dcrismond@ccny.cuny.edu) IS OUR LEAD RESEARCHER.

Standard 3. Classroom Instruction

When teaching engineering design, teachers use appropriate instructional strategies to engage all students in the design process and monitor their progress.

In doing this, teachers:

3.a Plan and adapt lessons – Set appropriate learning goals, adjust curricula and use inquiry/design-based instructional models (e.g., 5E, informed design) to create lessons that address students' specific learning needs.

3.b Support Integrative Learning – incorporate literacy, numeracy, and technology tasks effectively in design-based instruction.

3.c Encourage Team Work – Encourage all students to work collaboratively in teams, and share ideas and resources with peers.

3.d Use Formative Assessments – Use formative assessments to gather evidence of students' learning, provide timely feedback, and adjust daily instruction.

3.e Use Summative Assessments – Use assessments and performance rubrics to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.

Panel Member 15 Technology

Practice in developing clear problem statements.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Manage a project in designing and building a technical device that solves a problem.
Carry out the process for solving a problem.
Develop a design portfolio documenting the process for solving a problem.
Modeling and prototype development.

Panel Member 16 Science

1. Pre-service teachers must read the Framework and discuss with colleagues the research that drives the conceptual shifts. Watching videos of instruction is a good way to envision what should be happening.

2. Teacher educators need to introduce pre-service teachers to the resources available by NSTA and others that are research based in support of the NGSS and eng'g design. Pre-service teachers could keep a journal of their questions, their learning and their successes.

3. Teacher educators should engage pre-service teachers in eng'g design lessons to model the learning and intent of defining the problem in the NGSS. Pre-service teachers need to participate as students to understand the grade level student performance expectation differences. Teachers also struggle with the concept of constraints...they think it is about available materials or class time to build models of possible solutions...rather than what would constrain the solution designs themselves.

4. Teacher educators should engage pre-service teachers in collaborative analysis and critique of eng'g design resources available online and manufacturers. Pre-service teachers need to be critical consumers of what is available because very little engages students in defining the problem (most give students a challenge). They need to brainstorm eng'g scenarios/situations that present students with opportunities to define problems.

5. Teacher educators must communicate that revising lessons/units to align with NGSS must be a collaborative process with ES, PS and LS teachers. If is very difficult for one teacher, in isolation, to align lessons.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Panel Member 17 Science

1. Work through engineering models using science content.
2. Draw or reflect on safety, economics, human impact as part of the constraints of the problem.
3. Examine scenarios where science solved a problem and engineering solved the same problem--compare and contrast the two approaches.
4. Compare and contrast science and engineering models.

Panel Member 18 Technology

Teachers should: embrace ambiguity, be willing to say, "I don't know", guide students towards understanding a problem, teach methods that lend toward innovation and not just recreation.

Panel Member 19 Science

1. Discussion- engaging students in discussions surrounding the concepts of NGSS and the integration of subjects as well as how the engineering design practices should be embedded within the curriculum
2. Demonstrations of how various materials and/or activities can be utilized in the curriculum.
3.Cooperative learning/group work- to ensure that there are a diverse set of skills present and so students can see how teams are vital to the success of an engineering project.
4. Mini-lectures to provide key information to teachers on engineering design concepts as well as additional subject matter that may be new to them.
5.Media presentations- both teacher educators and pre-service teachers alike should be utilizing technology to show examples of collaborative work skills in engineering design as well as to present their findings.
6.Peer sharing- pre-service teachers need to be able to teach these concepts to others as well as present their findings in an effective manner.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Panel Member 20 Technology
Distinguish problems that require engineering solutions. Demonstrate ethical research procedures. Model safe use of tools. Exhibit engineering design exemplars.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Panel Member 1 Technology

Identify resources, parameters, values, etc.
Ask questions such as -
Is there another way to solve this problem or use these materials?
Can I borrow or adapt previous solutions or technologies?
Can I add a new element or twist that might lead to a solution?
Can I add more to the problem in an effort to find a solution?
Can I remove parts of the problem in an effort to solve it?
Can I incorporate substitutes or use other materials/techniques?
Can I rearrange the elements of the problem to find the solution?
Can I do the opposite of what I am currently thinking?
Can I combine elements or techniques to solve the problem?
Additionally, students must be able to sketch and complete finished drawings (or CAD drawings) of the proposed solution.

Panel Member 2 Technology

1. must understand and practice the 'design process'
2. know what 'engineering by designs' means
3. know and practice developing a method that allows them to 'know what to do when we don't know what to do' when developing problem solving skills

Panel Member 3 Technology

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

1. They must have a clear understanding and knowledge of the "T&E" components of STEM. At a minimum, they must know technology is about modifying the natural world to meet human needs and wants and engineering applies math and science to create technology.

2. They must know the engineering design process is used in engineering and technology to solve open-ended real-world problems. Although there are many variations, they should be able to describe the basic steps in the engineering design process.

3. They must know about the common approaches used in engineering and technology to solve problems (see Standards for Tech Literacy).

Panel Member 4 Technology

Teachers must provide opportunities for students to engage in hands-on, prototyping activities.

Teachers must provide students with age-appropriate design challenges.

Panel Member 5 Science

In order to adequately design engineering solutions as a practice they would teach students, K-12 pre-service science teachers must:

1. Be familiar with modeling as a tool for engineering design and problem-solving.
2. Identify multiple strategies for solving engineering problems.
3. Understand how solving engineering problems is a tool for understanding scientific concepts. K-12 teachers are not teaching engineering, but using it as an application tool. Designing a solution while emphasizing the main science content requires intentional planning and deliberate focus on the standard objectives.
4. Be able to formulate multiple solutions to an engineering problem and use content evidence to support the decision to use one over another.
5. Research real world contexts and understand the underlying engineering solutions being used. Then they must redesign these scenarios for a classroom setting.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Panel Member 6 Technology

1. Conceptual Mapping.
2. Lesson planning
3. Hands-on design activities.
4. Hands-on problem solving activities.
5. General technical skills and knowledge

Panel Member 7 Technology

1. Understand the steps of the engineering design process.
2. Understand how to integrate math, science, and other content areas using engineering design as the vehicle.
3. Know and demonstrate how to safely use tools and materials to construct engineering design solutions.

Panel Member 8 Science

Teachers must understand how to use models, variables, and computational thinking skills to design an engineering task. They must also persevere with debugging to solve engineering problems.

Panel Member 9 Science

Read
Write
Recognize activities that foster higher order thinking skills

Panel Member 10 Science

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Teachers must be able to adequately design engineering solutions to problems, explain to students how to design those solutions, and construct opportunities that allow students to design those solutions.

Panel Member 11 Technology

Knowledge and ability to use a variety of modeling tools (analytical, physical, virtual)
Knowledge of various idea-generating strategies
Knowledge of strategies for testing and analyzing design solutions
Understanding of the safety implications of design tasks given to students, and the ability to apply this understanding to judgments about selection of activities, tools, equipment in the classroom

Panel Member 12 Science

Know design cycle and experience it themselves as student learners

Panel Member 13 Technology

Should be able to perform the engineering design process.
Should understand engineering related problems.
Should have creative capacities to find solutions to problems.
Should be able to use design tools (hand, computer, simulation models, etc...many different not limited to traditional hand tools) to create solutions.
Understand design/engineer notebooks.

Panel Member 14 Technology

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

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2.c Generate Alternatives – Produce several different possible design solutions.

2.d Decide & Build – Balance benefits and tradeoffs in choosing a solution to build; use tools safely when making a prototype.

2.e Test Prototype – Design and perform experiments to test how the prototype works and meets the design criteria.

2.f Revise & Iterate – Use feedback from tests and ideas from others to refine and improve the prototype iteratively.

2.g Communicate & Reflect – Share design ideas and solutions and reflect on the design work, the processes used and decisions made.

Panel Member 15 Technology

Sketching and CAD Design work
Modeling parts and 3D printing
Material testing knowledge

Panel Member 16 Science

1. Pre-service science teachers need to know the reason for models in the NGSS and how models in eng'g design differ from models in science.

2. Pre-service teachers must appreciate the value of creativity, collaborative brainstorming and be able to model that for their students.

3. Pre-service teachers must take risks and value failures. As much is learned about a solution by design failures as by successes. They need the skills to create a classroom culture that supports collaboration and appreciates that designs should be tested to the point of failure.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

4. Pre-service teachers must have a strong understanding of the DCIs in LS, ES and PS. This is usually a deficiency in elementary teachers.
5. Pre-service teachers need organization systems to manage students' behaviors.
6. Pre-service teachers need to be able to analyze data and teach those strategies to their students.

Panel Member 17 Science

1. Understand how the engineering process works to design a solution.
2. Compare and contrast science and engineering approaches to solving problems.
3. Have enough of an understanding of the science to understand the engineering problem, and see connections between the science and the engineering.
4. Recognize the science content behind an engineering problem.
5. Explain the science content behind an engineering problem to students--help students describe or define the science content involved in the engineering problem.

Panel Member 18 Technology

How to make informed decisions, model, use systems thinking, use graphical communications, engage in reflection, optimize, have grit, understand the role of material resources or lack thereof.

Panel Member 19 Science

Same as section one-they must have had exposure to all the items listed in the previous section in or do adequately design engineering solutions and utilize the engineering design practices effectively.

Panel Member 20 Technology

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Clarify criteria.
Define constraints.
Model safe tool use.
Exhibit proper use of a variety of materials.
Demonstrate varying levels of aesthetic quality in engineering solutions.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Panel Member 1 Technology

Questioning, envisioning the solution (sketching, orthographic projection, perspective drawing, CAD drawing, etc.)

Panel Member 2 Technology

1. Define the difference between invention and innovation
2. Develop their problem solving skills by introducing 'real world' problems
3. Working in groups to 'brain-storm' ideas for solutions
4. Develop possible solutions
5. Actually develop models to their solutions
6. Collect data based on their solutions to the problem

Panel Member 3 Technology

1. They must know the engineering design process is used in engineering and technology to solve open-ended real-world problems. Although there are many variations, they should be able to describe the basic steps in the engineering design process.

2. They should be able to use B & 3D CAD Software and other types of modeling software.

3. They should be given hands-on experience using real-world tools and materials in the solving of an actual engineering type problem.

Panel Member 4 Technology

Teachers must employ coaching and facilitation methodologies.
Teachers must encourage a variety of solution possibilities.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Teachers must use group facilitation techniques.

Panel Member 5 Science

Instructional strategies include:

1. The immersion of pre-service teachers in modeling practices designed to solve engineering problems.
2. Instruction in the methodology of problem-solving and how it is applied to engineering practices.
3. Given an engineering problem, students are asked to formulate multiple engineering solutions. Then they must use scientific evidence and prior observation to determine which proposed solution might be most successful. Finally, students implement the solution to verify the success of the engineering design.
4. Students are given practice in drawing and sketching observed phenomena and engineering designs.
5. Students work in small groups and engage in regular peer review for the improvement of engineering designs.
6. Students engage in trial and error of design production and implementation.
7. Students are asked to reflect on how their design solutions enhance their knowledge of key scientific concepts identified by the NGSS standards.

Panel Member 6 Technology

1. Conceptual Mapping.
2. Lesson planning
3. Hands-on design activities.
4. Hands-on problem solving activities.
5. General technical skills and knowledge.

Panel Member 7 Technology

1. Model safer use of engineering tools, machines, and processes to design engineering design solutions.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

2. Demonstrate how to intentionally integrate multiple content areas into science instruction using engineering design.
3. Intentionally identify steps of the engineering design process that students explain they went through when summarizing their experience.
4. Identify areas where the lesson could be enriched with greater STEM connections or authentic engineering design.

Panel Member 8 Science

Teacher educators should give pre-service teachers engineer assignments that require debugging. Teachers need to be able to see where problems may arise in order to help their students.

Panel Member 9 Science

Design Act Learning Teaching Strategies incorporated into Case Study exploration and resolution.

Panel Member 10 Science

Pre-service teachers should experience situations where they are exposed to problems that require an engineering-type solution (so that they can experience the process).

Panel Member 11 Technology

Guided practice
Demonstrations
Engage students in sample design activities that would be appropriate for the target grade levels they will teach

Panel Member 12 Science

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Again, know what engineers do and experience hands on content based engineering design challenge activities in their content area (bio, Chem, physics).

Should learn cooperative learning strategies, group discourse tools and inquiry (data collection and analysis) as well as argumentation skills

Panel Member 13 Technology

Practice with design problems.
Expose future teachers to many different design methods.
Require students to document their design work with notebooks.
Connect the design problems and process to the students "real world" life.

Panel Member 14 Technology

Iterative Design
Modeling (representational and predictive)
Systems Thinking
Select and Using Appropriate Resources
Consider Human Factors (e.g., health, safety, and ergonomics) and Environmental Impacts when Proposing Design Solutions.

Panel Member 15 Technology

Design teams
Concurrent engineering
Capstone projects

Panel Member 16 Science

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Teacher Education must engage the pre-service teachers in the NGSS practices to skills to implement with focus on
1. Collaborative brainstorming.
2. Classroom culture that supports risk taking.
3. Participate in design building, testing and data collection.
4. Model Engaging in argument from evidence.

Panel Member 17 Science

1. Ensure a solid foundation in appropriate science content--depth and breadth. Enough courses, appropriate focus.
2. Expose students to engineering problems and processes applied to specific science content.
3. Study excellent, good, and poor lessons that model science content and engineering--identify and evaluate strengths and weaknesses of the lessons.
4. Write lessons for an engineering application of science content.
5. Expose students to engineering practices, what does an engineer really do and how do they do it? Help understand the engineering process.

Panel Member 18 Technology

Help students cope with failure; deal with student resistance when there is not a clear path - as most engineering design problems are ill-defined, use formative assessment methods.

Panel Member 19 Science

1. Discussion- engaging students in discussions surrounding the concepts of NGSS and the integration of subjects as well as how the engineering design practices should be embedded within the curriculum
2. Demonstrations of how various materials and/or activities can be utilized in the curriculum.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

3. Cooperative learning/group work- to ensure that there are a diverse set of skills present and so students can see how teams are vital to the success of an engineering project.

4. Mini-lectures to provide key information to teachers on engineering design concepts as well as additional subject matter that may be new to them.

5.Media presentations- both teacher educators and pre-service teachers alike should be utilizing technology to show examples of collaborative work skills in engineering design as well as to present their findings.

6. Peer sharing- pre-service teachers need to be able to teach these concepts to others as well as present their findings in an effective manner.

Teacher educators need to provide authentic experiences to pre-service science teachers in order for them to have first-hand experience and know what to do with their own students.

Panel Member 20 Technology

Model visualization techniques.
Demonstrate a structured process for designing engineering solutions.
Produce design documentation that can be replicated.

Section 3. Question 1E. Instructional Strategies (Sec3-QA)

Panel Member 1 Technology

Understand cause-effect relationships (e.g., What parts of systems affect and are affected by other parts?)
Make comparisons (e.g., What commonalities and differences do systems have?)
Recognize probable outcomes (e.g., How will the system react to a specific action?)
Predict what should happen next (e.g., Based on what has been observed, what is known about a specific system, and what is known about related scientific principles, make a prediction about what will happen next.)
Judge spatial relationships (e.g., Visualize how a system operates and mentally rotate system parts to solve problems within a given system.)
Notice what appears out of place (e.g., Observe a malfunctioning system in operation to determine what is not working correctly.)

Panel Member 2 Technology

1. Allow students to follow a 'guided practice' that allows them to introduce targeted science content into their classroom.

Panel Member 3 Technology

I would develop standards-based activities and experiences that require student to apply both the engineering design process and scientific method in the solving an engineering/technology problem. In this activity or experience, I would also require them to identify and discuss all important STEM concepts associated with the activity or experience.

Panel Member 4 Technology

Teacher educators should provide opportunities for teacher education candidates to learn how to develop and facilitate the implementation of age-appropriate engineering design challenges. They should be prepared to distinguish between engineering and science concepts and to understand how the two function to facilitate learning. They should help students learn how to manage open-ended, group-oriented projects and how to assess the outcomes (both formative and summative).

Section 3. Question 1E. Instructional Strategies (Sec3-QA)

Panel Member 5 Science

The use of inquiry instruction and a focus on Nature of Science pedagogy in science classrooms has become common practice in science teacher preparation. As students engage in authentic scientific processes, they reconstruct their knowledge related to a particular content area. These practices engage students in scientific questioning and investigation using relevant contexts and applications.

I view the addition of engineering practices to the standards in much the same way. We must engage our pre-service teachers in the process of identifying the key science content, exposing them to scientific phenomena, determining the questions and (now) engineering problems that put this content into real world contexts, and design investigative and/or engineering solutions that will increase our understanding of the content.

The key to intentionality is to continuously frame the activities as a tool for getting to the science content objectives of the NGSS standard we're addressing. The inquiry and the scientific process and the engineering design are all tools to engage students brains in a way to accurately and completely conceptualize scientific content, and be able to employ it in the real world.

Instructional strategies include both science-specific pedagogical approaches to engage the process of learning (e.g. the use of inquiry and modeling curriculum), and the continuous assessment of whether these approaches are progressing content knowledge identified in the NGSS standards. We model these practices for our pre-service teachers, who will then do them with their future students.

Panel Member 6 Technology

1. Conceptual Mapping.
2. Lesson planning
3. Hands-on design activities.

Section 3. Question 1E. Instructional Strategies (Sec3-QA)

4. Hands-on problem solving activities.
5. General technical skills and knowledge.

Panel Member 7 Technology

1. These science educators must first have the engineering content and practices knowledge to know what to point out to their pre-service teachers. Many of the faculty training science teachers have no clue about teaching engineering and do not want to collaborate with engineering educators. So that is the first problem, they need to bring in engineering educators and teach their students how to collaborate with engineering educators or where to find them (ex. ITEEA, ASEE, etc.)

2. They need to intentionally point out these cross-disciplinary intersections to their students when they occur. They can't assume students will make the connection.

3. They should provide additional resources for their students to use for various content areas to better understand it and intentionally integrate it. Resources could be websites, handouts, expert guest speakers, etc.

Panel Member 8 Science

There are several rubrics that measure how well teachers engage students in STEM activities, specifically engineering tasks. One such rubric or tool is the Dimensions of Success (DoS). Teacher educators should share this instrument and hep pre-service teachers understand how to best attend to each one, particularly student learning outcomes such as STEM engagement, STEM content learning, and inquiry.

Panel Member 9 Science

Assignments that send students into journals that explain what works and doesn't work in classroom settings where NGSS is being implemented.

Panel Member 10 Science

Section 3. Question 1E. Instructional Strategies (Sec3-QA)

There is a lot of overlap between scientific practices and engineering practices. The latter is best suited for practical problems, which can be used to make the science content relevant. Consequently, pre-service teachers should engage in experiences where practical problems are used as the context for exploring scientific content.

Panel Member 11 Technology

Make students aware of the educational objectives: what are key concepts to be learned? Analyze sample design activities to try to 'unpack' science content. Provide critiques of the appropriateness/effectiveness of the activity. Use short video clips or actual teaching sequences to illustrate how a master teacher USES the design activity to teach targeted science content. Carry out design activities that are considered exemplary: Let pre-service teachers experience a well-design activity and then discuss it afterward

Panel Member 12 Science

Model how to do this in methods courses with multiple examples. Show curriculum like engineering is elementary (or secondary version of this) and have students design lesson plans, teach and reflect on these lessons

Panel Member 13 Technology

Look at the engineering design process as a pedagogically method, as well as a content method. I think science teachers need to see the wealth of opportunity to not only teach the "method" of design, but also the engaging way they can use the method as a pedagogically tool to transfer other content knowledge to the students.

Revisit the NGSS and investigate ways the design process can be used to teach specific content by combining different standards and benchmarks.

Panel Member 14 Technology

Section 3. Question 1E. Instructional Strategies (Sec3-QA)

Use authentic contexts the require STEM understandings to solve problems that have a societal dimension (e.g., making contaminated water potable; providing food for the expanding global population).

Focus on a limited number of concepts

Focus on broad themes rather than atomistic competencies.

Panel Member 15 Technology

Technological problem solving technique

Utilize scientific physics, and chemistry principles for the basis of the design of a solution to a problem

Practice the iterative process of design/re-design.

Panel Member 16 Science

I feel that I am repeating myself. Teacher educators need to

1. Model who to integrate science teaching in eng'g design.
2. Engage pre-service teachers as K-12 students
3. Help pre-service teachers identify eng situations/scenarios that enable the integration of science content in their lesson/unit design

Teacher educators & pre-service student teachers must understand for themselves that if students don't have the science content understandings to address eng'g design, then they will be guessing at the cause of the problem, possible solution designs, etc.

Panel Member 17 Science

1. Lessons or activities that explicitly ask students to apply engineering practices to a problem clearly linked to science content.
2. Lessons and activities where students are faced with an engineering problem. Students define, then learn, the science content needed to solve the problem.
3. Ask students to critique engineering lessons to look for the science, and science lessons to look for the engineering.

Section 3. Question 1E. Instructional Strategies (Sec3-QA)

4. Model lessons where science content is taught through engineering practices and make it explicit to students that this was the approach and why/how it works.

Panel Member 18 Technology

While understanding the science content objective to be met, engineering is one of those content areas in NGSS. So, engineering is not just a pedagogical method, but a way of thinking and doing. It is far too easy for a teacher to say they are doing engineering when in reality, they are not.

Panel Member 19 Science

Cooperative learning, hands on/minds on activities and instruction, problem based learning, inquiry based activities and discussions, scientific argumentation.

Panel Member 20 Technology

Create tools and instrumentation for collecting scientific data.
Contrast processes used by scientists with those used by professionals in other disciplines.
Exhibit techniques for questioning different phenomena.

Panel Member Comments
Panel Member 4 Technology

Panel Member Comments
In our experience with science teachers, design challenges too often come out looking like scientific experimentation. Science teachers typically have a difficult time developing and implementing authentic, multi-solution design challenges. Our experience has also been that discussions about engineering and the standards only go so far and tend to occur in the abstract. It's when teachers begin to design and implement engineering-oriented lessons that they begin to understand how the engineering reinforces the learning of science concepts. **Panel Member 5 Science** The addition of engineering practices to the science standards should be seen as an extension of what teachers should already be doing with inquiry, active learning and the process of science. While the engineering skills are unique from other science process skills, they are certainly related to the pedagogical ideas of engaging curiosity and actively questioning and problem-solving for meaningful learning. Whatever framework is developed to help progress the instruction of pre-service teachers in this area should probably build on what science teachers are already doing well, intentionally developing engineering-specific skills but not isolating them entirely from the collective science teacher's instructional tool box. **Panel Member 6 Technology** I am curious; is the assumption here that Integrated STEM is the form of the future? If so, has it also been decided that science teachers are the ones best prepared to teach technology and engineering? I realize this is a political issue nationally, and I think we need to be careful here. Are we suggesting that there is one curriculum and in the future one certification route (i.e., Integrated STEM teachers)? I do see that in my state or in surrounding states. **Panel Member 7 Technology**

Panel Member Comments
Like I said in the last question response - I think before science educators can truly teach engineering content and practices they need to fully understand what it is and have a stronger content knowledge in that area. They already have too much content to cover and now are expected to teach engineering. From what I've witnessed it is usually just treated as an arts and crafts time or non-design based engineering add on to a science lesson (ex. everyone construct this design using the same parts and set of directions). I have attended and presented at both the ITEEA conference and the NSTA conference over the past few years and noticed science educators' level of engineering content and pedagogical knowledge is not near what T&E educators' is (as would be expected based on their preparation). But the difference is that T&E educators seem more open to collaborate and work with other content areas. I've noticed science has tried to address engineering design on their own and don't care to work with T&E educators (or even know they exist) and that is where Integrative STEM Education is lacking - the need for more collaboration between the science ed and T&E ed communities. I also strongly believe T&E educators can teach engineering design at a different level with their tool, machine, and materials expertise. It is very scary to think of science educators using power tools in their classrooms to address engineering design when they have no training in this area! Again this is why collaboration is the best approach to achieve the highest level of intentional integration among STEM concepts.
Panel Member 9 Science
Pre-service teachers have GOT to understand that this PROCESS - the teaching of Disciplinary Core Ideas, using Science and Engineering Practices/Cross Cutting Concepts, is to be measured by Observable Performance Expectations - NOT paper and pencil recitation of facts. Assessments must be aligned to the PEs. More time should be spent addressing this changing paradigm.
That's all for now.
Panel Member 10 Science
For there to be a difference between scientific practices and engineering practices, there must exist problems for which scientific practices are insufficient and one must instead use engineering practices. These tend to be situations where the science content can be either too difficult to master or too inefficient to apply. Consequently, teachers may inadvertently gloss over scientific content in an attempt to implement engineering practices. While I think it is important for students to be able to identify the relevant variables and whether a problem is solvable, in practice I think it is better not to separate this from scientific practices.

Panel Member Comments
Panel Member 14 Technology
Important to keep in mind that science teachers have limited time to devote to engineering; therefore, activities that evolve must be kept within a reasonable (7-10 day) time frame.
Panel Member 15 Technology
Good luck with the project!
Panel Member 16 Science
I look forward to reading about your research findings.
Panel Member 18 Technology
Engineering design activities offer the promise of enhanced learning and teaching in pre-college STEM settings. However, the wide variation and lack of coherence with pre-college engineering design research and practice results in a broad and watered down version of what engineering design really can be at K12.

Appendix J

Round 1 Theme Analysis

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Ability to do Hands on Investigations	P14 T Sec1QA	Research & Investigate – **Do** research and **hands-on investigations** to gather insights/information about the challenge.	The panel member used the statements **hands on, and investigation**. The content of these statements addresses PST ability to do hands on investigations.	do hands on investigations to gather insights/information about engineering design challenges.
Ability to Explain Engineering Problems	P10 S Sec1QA	**Explain** to students what makes a problem an **engineering problem**	Panel members used the statements **explain, communicate, identify, engineering problems**. The content of these statements addresses PST ability to communicate in spoken form.	explain engineering problems.
	P20 T Sec1QA	**Communicate** a structured process for investigating **engineering problems.**		
	P10 S Sec1QA	Teachers must be able to **identify** what counts as an **engineering problem** (i.e., a problem can be solved using accessible material and equipment),		
	P18 T Sec1QA	Being **able** to write out or **explain** a **problem** is paramount.		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Ability to Identify Multiple Solutions	P10 S Sec1QA	Explore **multiple** trials in an attempt to **identify** possible paths to **solutions.**	The panel member used the **statements multiple, identify and solutions.** The content of this statement addresses PST ability to identify multiple solutions.	identify multiple solutions to an engineering problem.
Ability to Research Design Challenges	P14 T Sec1QA	Research & Investigate – **Do research** and hands-on investigations to gather insights/information about the **challenge**.	Panel members used the statements do **research and access information.** The content of these statements addresses PST ability to able to research solutions to a problem.	research solutions to an engineering problem.
	P18 T Sec1QA	Knowing how to **access information** that is relevant to the problem; this can be electronic sources as well as human.		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Ability Explain Problems in Written Form	P18 T Sec1QA	Being **able** to **write out** or explain a **problem** is paramount.	The panel member used the statements **able, write out, and problem.** The content of this statement addresses PST ability to explain problems in written form.	explain engineering design problems in written form.
Ability to Ask Questions	P18 T Sec1QA	Knowing **how** to **ask questions**.	The panel member used the statements **how, asks, and questions.** The content of this statement addresses PST ability to ask questions.	ask questions about engineering problems.
Analyze STEM Learning Experiences	P19 S Sec1QA	Implement and **analyze STEM learning experiences** regarding their focus on State Curriculum Standards for Mathematics, Science, Technology, and Engineering–Grades K-8 (MSDE)	The panel member used the statements **analyze STEM and learning experiences.** The content of this statement addresses PST ability to analyze STEM learning experiences.	analyze STEM learning experiences regarding their focus on state curriculum standards.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Apply Disciplinary Core Ideas	P16 S Sec1QA	Situations should be relevant, observable, and specific and **apply DCIs** in the life, earth and physical sciences. For example, if a lake has dying fish...this is the situation/scenario.	Panel members used the statement **apply DCIs** The content of these statements address PST ability to apply Disciplinary Core Ideas.	apply Disciplinary Core Ideas
	P16 S Sec1QA	Students would need to **apply** their understanding of the **DCIs** to define what is causing the fish to die, i.e... chemicals, food web? Or if it is too hot in the room, students would need to decide what is causing the discomfort, i.e... lack of ventilation, shade, personal preference.		
Apply Logical Thinking to Plan Engineering Tasks	P6 T Sec1QA	The ability to **think logically**.	The panel member used the statement **think logically**. The content of this statement addresses PST ability to apply logical thinking to plan engineering tasks.	demonstrate logical thinking when planning engineering tasks.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Apply STEM Pedagogical Concepts	P19 S Sec1QA	**Apply STEM pedagogical concepts**, in Design, Technology and Engineering Education in STEM focused curricular models.	The panel member used the statement apply **STEM pedagogical concepts.** The content of this statement addresses PST ability to apply STEM pedagogical concepts.	apply STEM pedagogical concepts, in design, technology and engineering education in STEM focused curricular models.
Assess Student Understanding by Observation	P8 S Sec1QA	They should be able to make **observations** and **assess** student understanding based on these concepts as well.	The panel member used the statements **observations** and **assess**. The content of this statement addresses PST ability to assess student understanding by observation.	assess student understanding of inquiry, scientific processes and computational thinking through observations.
Break Problem Into Smaller Parts	P1 T Sec1QA	**Break it into small parts**, and determine what exactly needs to be done.	Panel members used the statement **break it into small parts**. The content of these statements addresses PST ability to break content into smaller parts.	break engineering problems into smaller parts.
Contextual Reading Skills	P9 S Sec1QA	**Read** for **contextual** clues	The panel member used the statement **read for contextual clues**. The content of these statements addresses PST ability to read for contextual clues.	read engineering design problems for contextual clues.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Define Computational Thinking	P8 S Sec1QA	Teachers must be able to understand and **define** inquiry, scientific processes and **computational thinking**.	The panel member used the statements **define and computational thinking**. The content of these statements addresses PST ability to define computational thinking.	define what computational thinking is.
Define Design Constraints	P20 T Sec1QA	**Define constraints.**	The panel member used the statement **define constraints.** The content of these statements addresses PST ability to define constraints.	define the constraints of engineering problems.
Define Engineering Problems	P5 S Sec1QA	Teachers must be able to **define engineering problems** as design challenges that can be solved.	The panel member used the statement **define engineering problems**. The content of these statements addresses PST ability to define engineering problems.	define an engineering problem.
	P18 T Sec1QA	Understand constraints, tradeoffs, **problem definition,** personal beliefs and how they influence a **design.**		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Define Problems	P13 T Sec1QA	They should be able to adequately **define problems** themselves.	The panel member used the statement **define problems**. The content of these statements addresses PST ability to define problems.	define a science problem.
	P16 S Sec1QA	Possible solutions will vary depending on how students **define** the **problem**,		
Define Scientific Inquiry	P8 S Sec1QA	Teachers must be able to understand and **define inquiry,** scientific processes and computational thinking.	The panel member used the statement **define inquiry**. The content of these statements addresses PST ability to define scientific inquiry.	define the meaning of scientific inquiry.
Define Technology	P3 T Sec1QA	At a minimum, they must **know technology is about** modifying the natural world to meet human needs and wants	The panel member used the statement know **technology is about.** The content of these statements addresses PST ability to define technology.	demonstrate that technology is about modifying the natural world to meet human needs and wants.
Define What Engineering Means	P11 T Sec1QA	Be able to explain or **define** what engineering is and wha**t** **engineering means**	The panel member used the statements define and engineering means. The content of these statements addresses PST ability to define what engineering means.	define the meaning of engineering.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Define What Engineering Is	P11 T Sec1QA	Be able to explain or **define** what **engineering is** and what engineering means	The panel member used the statements **define and engineering is**. The content of these statements addresses PST ability to define what engineering is.	define what engineering is.
Describe Engineering Process	P3 T Sec1QA	Although there are many variations, they should be able to **describe** the basic steps in the **engineering design process**	The panel member used the statements **describe and engineering design**. The content of these statements addresses PST ability to describe the engineering process.	describe the basic steps of the engineering design process.
Design Instructional Environments that Accommodate Inquiry-Based Pedagogies	P19 S Sec1QA	**Design instructional environments** that that accommodate **inquiry-based pedagogies,** meet institutional goals of sustainability, are welcoming destinations, and support interdisciplinary collaborations.	The panel member used the statements **design instructional environments and inquiry-based pedagogies.** The content of these statements addresses PST ability design instructional environments to accommodate inquiry-based pedagogies.	design instructional environments that accommodate inquiry-based pedagogies.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Design Lessons that Provide Contextual Clues	P9 S Sec1QA	**Prepare** teaching **materials** that **provide contextual clues** to engineering based problems.	The panel member used the statement **prepare, materials** and **contextual clues**. The content of these statements addresses PST ability design instructional environments to provide contextual clues.	prepare teaching materials that provide contextual clues to engineering based problems.
Determine Engineering Practices	P4 T Sec1QA	**Determine** which scientific questions may be addressed using **engineering practices**.	The panel member used the statements **determine and engineering practices.** The content of these statements addresses PST ability to determine engineering practices.	determine which scientific questions may be addressed using engineering practices.
Develop Solutions	P1 T Sec1QA	Break it into small parts, and **determine** what exactly needs to be done.	The panel member used the statements **determine, develop and solutions** The content of these statements addresses PST ability to develop solutions.	develop solutions to engineering problems.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
	P2 T Sec1QA	**Develop** possible **solutions** based on their research		
Differentiate Between Scientific Inquiry and Engineering Design	P4 T Sec1QA	Distinguish the **difference** between **science questions** and **engineering problems**.	Panel members used the statements **difference, science (questions), and engineering (problems)** The content of these statements addresses PST ability to differentiate between the practices of scientific inquiry and engineering design.	differentiate between the practices of scientific inquiry and engineering design.
	P6 T Sec1QA	Understanding of how **engineering** is **different** from **science**.		
	P7 T Sec1QA	Understand the **difference** between **engineering design** and **scientific inquiry.**		
	P12 S Sec1QA	They have to know how **science** and **engineers** work together and how they are **different** (knowledge vs application).		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
	P13 T Sec1QA	Understand the field of engineering and how **engineering problems** are **different** from **experimental problem**s.		
	P15 T Sec1QA	Distinguish the **difference** between **problem statements** and their **solution.**		
	P17 S Sec1QA	Describe and use a model of the **engineering process,** and that this process **differs** from the **scientific method**.		
Embed Engineering Activities	P12 S Sec1QA	They should experience content **embedded engineering activities**, should understand how to teach content as well as engineering practices.	The panel member used the statement **content embedded engineering activities**. The content of these statements addresses PST ability to embed engineering activities into content.	embed engineering activities into science content.
Explain Engineering Process	P17 S Sec1QA	**Describe** and use a model of the **engineering process**, and that this process differs from the scientific method.	The panel member used the statements **describe and engineering process.** The content of these statements addresses PST ability to explain the engineering process.	explain how the engineering process differs from the scientific method...

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Explain What Engineering Means	P11 T Sec1QA	Be able to explain or define what engineering is and what engineering means	The panel member used the statements **explain and engineering means.** The content of these statements addresses PST ability to explain what engineering means.	explain the meaning of engineering.
Explained What Engineering Is	P11 T Sec1QA	Be able to **explain** or define what **engineering is** and what engineering means	The panel member used the statements **explain and engineering is.** The content of these statements addresses PST ability to explain what engineering is.	explain what engineering is.
Facilitate Development of Engineering Design	P14 T Sec1QA	When teaching engineering design, teachers facilitate students' development of engineering design thinking and practices.	Panel members used the statements **facilitate, development, practices, and engineering design.** The content of these statements addresses PST ability to facilitate the development of	facilitate student development of engineering design practices.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
			engineering design practices.	
Focus on Practical Solutions to a Problem	P17 S Sec1QA	**Focus** of engineering on a **practical solution** to a **problem**.	The panel member used the statements **focus, practical solution and problem**. The content of these statements addresses PST ability to focus on practical solutions to a problem.	focus on practical engineering solutions to a problem.
Group Work	P2 T Sec1QA	**Work** in small **groups** in a cooperative manner	The panel member used the statements **work and groups**. The content of these statements addresses PST ability to work in small groups	work in small cooperative groups.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Concepts of other areas of Academia, such as Economics, Engineering, Human Impact, Safety, & Technology	P3 T Sec1QA	Given a matrix listing the STEM areas, pre-service teachers should be able to **identify concepts** and practices that occur in each **of the areas** especially in those practices and content related to technology and engineering education.	Panel members used the statements **identify, each of the areas, requires, knowledge, of other areas.** The content of these statements addresses PST ability to identify concepts of other areas of academia.	identify the concepts that occur in economics, engineering, human impact, safety, and technology and how they related to technology and engineering education.
Identify Design Constraints	P1 T Sec1QA	**Identify** the **constraints**	Panel members used the statements **identify, clarify, and constraints.** The content of these statements addresses PST ability to identify constraints on a design problem.	identify the constraints on an engineering problem.
	P5 S Sec1QA	Teachers must be able to **identify** restrictions or **constraints** for design challenges.		
	P14 T Sec1QA	Understand Challenge – Understand the design challenge by **identifying** desired performances, criteria and **constraints**.		
	P20 T Sec1QA	**Clarify criteria.**		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Design Criteria	P14 T Sec1QA	Understand Challenge – Understand the design challenge by **identifying** desired performances, **criteria** and constraints.	The panel member used the statements **identify and criteria**. The content of these statements addresses PST ability to identify design criteria.	identify engineering design criteria.
Identify Design Performances	P14 T Sec1QA	Understand Challenge – Understand the design challenge by **identifying** desired **performances**, criteria and constraints.	The panel member used the statements **identify and performances.** The content of these statements addresses PST ability to identify design performances.	identify engineering design performances.
Identify Educational Standards	P3 T Sec1QA	They should be able to **identify** the **educational standards** that are used in each of the STEM fields.	Panel members used the statements **identify and educational standards.** The content of these statements	identify the critical content and skills objectives of an educational standard in order to intentionally focus

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
			addresses PST ability to identify educational standards.	the development of engineering problems during a lesson.
	P4 T Sec1QA	**Identify** the critical content and skills objectives of a **standard** in order to intentionally focus the development of engineering problems during a lesson.		
Identify Engineering Problems	P20 T Sec1QA	**Distinguish** problems that require **engineering solutions.**	The panel member used the statements **distinguish and engineering** solutions. The content of these statements addresses PST ability to identify engineering problems.	identify engineering problems that require engineering solutions.
Identify Grade & Age Appropriate Content	P2 T Sec1QA	**Determine** what do students 'need to know' to solve the problem	Panel members used the statements **determine, identify, level appropriate.** and educational standards. The	identify grade and age appropriate engineering content.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
	P6 T Sec1QA	**Identify** what general education aspects of engineering are **appropriate** for K-12 students.	content of these statements addresses PST ability to identify grade and age appropriate content.	
	P9 S Sec1QA	**Identify** student **level** of reading comprehension.		
	P11 T Sec1QA	**Understand** the **concepts** of parameters, constraints, and specifications, and be able to explain these in **age-appropriate** ways to students		
Identify Interdisciplinary Connections	P19 S Sec1QA	Design instructional environments that that accommodate inquiry-based pedagogies, meet institutional goals of sustainability, are welcoming destinations, and support **interdisciplinary collaborations**	The panel member used the statement **interdisciplinary collaborations.** The content of these statements addresses PST ability to identify interdisciplinary connections.	identify interdisciplinary connections to engineering.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Personal Beliefs Influence Design	P18 T Sec1QA	**Understand** constraints, tradeoffs, problem definition, **personal beliefs** and how they **influence a design**.	The panel member used the statements **understand, personal beliefs, and influence a design.** The content of these statements addresses PST ability to identify how personal beliefs influence design.	identify how personal beliefs influence engineering design.
Identify Practices of Academia, such as Economics, Engineering, Human Impact, Safety, & Technology	P3 T Sec1QA	Given a matrix listing the STEM areas, pre-service teachers should be able to **identify** concepts and **practices** that occur in each **of the areas** especially in those practices and content related to technology and engineering education.	Panel members used the statements **identify, practices, and of the areas.** The content of these statements addresses PST ability to identify other practices of academia, such as economics, engineering, human impact, safety, & technology.	identify other practices of academia, such as economics, human impact, and safety, and relate them to practices of engineering and science.
	P17 S Sec1QA	Engineering requires science **content knowledge** but also knowledge of **other areas**--like economics, human impact, safety.		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify STEM Concepts	P3 T Sec1QA	Given a matrix listing the STEM areas, pre-service teachers should be able to **identify concepts** and practices that occur in each of the areas	The panel member used the statements **STEM and identifies concepts**. The content of these statements addresses PST ability to identify the concepts of each of the STEM fields.	identify the technology and engineering concepts of each in the STEM fields.
Identify STEM Practices	P3 T Sec1QA	Given a matrix listing the STEM areas, pre-service teachers should be able to **identify** concepts and **practices** that occur in each of the areas	The panel member used the statements **STEM and identifies practices.** The content of these statements addresses PST ability to identify the practices of each of the STEM fields.	identify the technology and engineering practices in each of the STEM fields.
Implement Design Based Instructional Strategies	P19 S Sec1QA	**Implement Design,** Technology and Engineering Education Instructional Methods & **Strategies** in technology and engineering and STEM focused curricular applications.	The panel member used the statements **implement design and strategies.** The content of these statements addresses PST ability to implement design strategies.	implement design based strategies in technology and engineering and STEM focused curricular applications.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Implement Design Based Instructional Methods	P19 S Sec1QA	**Implement Design,** Technology and Engineering Education **Instructional Methods** & Strategies in technology and engineering and STEM focused curricular applications.	The panel member used the statements **implement design and instructional methods**. The content of these statements addresses PST ability to implement design instructional methods.	implement design based instructional methods in technology and engineering and STEM focused curricular applications.
Implement STEM Learning Experiences	P19 S Sec1QA	**Implement** and analyze **STEM learning experiences** regarding their focus on State Curriculum Standards for Mathematics, Science, Technology, and Engineering–Grades K-8 (MSDE)	The panel member used the statements **implement and STEM learning experiences.** The content of these statements addresses PST ability to implement STEM learning experiences.	implement STEM learning experiences according to state standards.
Implement Technology and Engineering Instructional Methods	P19 S Sec1QA	**Implement** Design, **Technology and Engineering** Education **Instructional Methods** & Strategies in technology and engineering and STEM focused curricular applications.	The panel member used the statements **implement, technology and engineering, and instructional methods.** The content of these statements addresses PST ability to implement technology and engineering instructional methods.	implement technology and engineering instructional methods.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Implement Technology and Engineering Strategies	P19 S Sec1QA	**Implement** Design, **Technology and Engineering** Education Instructional Methods & **Strategies** in technology and engineering and STEM focused curricular applications.	The panel member used the statements **implement, technology and engineering, and instructional strategies**. The content of these statements addresses PST ability to implement technology and engineering instructional strategies.	implement technology and engineering instructional strategies.
Make Scientific Observations	P4 T Sec1QA	**Make scientific observations** of phenomenon and formulate multiple ideas, questions and problems related to those observations.	The panel member used the statement **make scientific observations.** The content of these statements addresses PST ability to make scientific observations.	make scientific observations to formulate multiple ideas, questions and problems related to those observations. .
Meet Institutional Goals of Sustainability	P19 S Sec1QA	Design instructional environments that that accommodate inquiry-based pedagogies, **meet institutional goals of sustainability,** are welcoming destinations, and support interdisciplinary collaborations	The panel member used the statement **meet institutional goals of sustainability.** The content of these statements addresses PST ability to meet the institutional goals of sustainability.	meet the institutional goals of sustainability.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Model Engineering Process	P17 S Sec1QA	Describe and use a **model** of the **engineering process,** and that this process differs from the scientific method.	The panel member used the statement **model engineering process.** The content of these statements addresses PST ability to model the engineering process.	model the engineering process to demonstrate that this process differs from the scientific process.
Model Ethical Research Procedures	P20 T Sec1QA	**Model ethical research procedures.**	The panel member used the statement **model ethical research procedures.** The content of these statements addresses PST ability to model ethical research procedures.	model ethical research procedures.
Problem Analysis	P1 T Sec1QA	Identify and **clarify** the **problem**, ask questions,	Panel members used the statements **clarify, analyze, and problem**. The content of these statements addresses PST ability to analyses problems.	analyze engineering problems.
	P1 T Sec1QA	Carefully **analyze** the **problem**		
Problem Identification	P1 T Sec1QA	**Identify** and clarify the **problem**, ask questions,	Panel members used the statements **identify, determine, and problem.** The content of	identify engineering problems.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
	P2 T Sec1QA	**Determine** the '**problem**'	these statements addresses PST ability to identify problems.	
Promote Risk Taking	P10 S Sec1QA	Construct **opportunities** that allow students to **take risks** and	The panel member used the statements **opportunities, and take risk.** The content of these statements addresses PST ability to promote risk taking.	take risk when solving engineering problems.
Provide Meaningful Examples	P11 T Sec1QA	Be able to **provide examples** of engineering and engineering problems that will be **meaningful** to and understood by their students	The panel member used the statements **provide examples, and meaningful.** The content of these statements addresses PST ability to provide meaningful examples.	provide meaningful examples of engineering and engineering problems that will be understood by their students.
Select Grade & Age Appropriate Curriculum	P11 T Sec1QA	**Select** engineering design scenarios or challenges purposefully, with the goal of selecting those that enable application of scientific concepts germane to the **grade level curriculum**, and that are within the students' range of capability	The panel member used the statements s**elect and grade level curriculum.** The content of these statements addresses PST ability to select grade and age approached curriculum.	select grade and age appropriate engineering design scenarios and challenges that enable the application of scientific concepts.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Solve a Problem Using Technology	P15 T Sec1QA	Clearly and succinctly define a problem that can be **solved** via **technical means**.	The panel member used the statements **solved, and technical means.** The content of these statements addresses PST ability to solve a problem using technology.	define a problem that can be solved using technical means.
Solve a Problem Using the Engineering Design Process	P7 T Sec1QA	Have gone through and **experienced** a true **engineering design based problem** before.	The panel member used the statements **experienced and engineering design based problem**. The content of these statements addresses PST ability to solve a problem using the engineering design process.	use the engineering design process to solve a problem.
Understand Computational Thinking	P8 S Sec1QA	Teachers must be able to **understand** and define inquiry, scientific processes and **computational thinking**.	The panel member used the statements **understand and computational thinking.** The content of these statements addresses PST ability to understand computational thinking.	understand computational thinking.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Concepts of Grade & Age Appropriate Activities	P11 T Sec1QA	**Understand** the **concepts** of parameters, constraints, and specifications, and be able to explain these in **age-appropriate** ways to students	Panel members used the statements **understand, constraints, and age appropriate.** The content of these statements addresses PST ability to understand the concepts of grade and age appropriate activities.	understand the concepts of grade and age appropriate engineering activities.
	P11 T Sec1QA	**Understand** the concepts of parameters, **constraints**, and specifications, and be able to explain these in **age-appropriate** ways to students		
Understand Design Challenges	P14 T Sec1QA	Understand Challenge – **Understand** the **design challenge** by identifying desired performances, criteria and constraints.	The panel member used the statements **understand and design challenge.** The content of these statements addresses PST ability to understand design challenges.	identify the desired performances, criteria and constraints of an engineering design challenge.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Design Constraints	P18 T Sec1QA	**Understand constraints,** tradeoffs, problem definition, personal beliefs and how they influence a design.	The panel member used the statement **understand constraints.** The content of these statements addresses PST ability to understand design constraints.	understand the design constraints of an engineering problem.
Understand Design Tradeoffs	P18 T Sec1QA	**Understand** constraints, **tradeoffs,** problem definition, personal beliefs and how they influence a design.	The panel member used the statements **understand and tradeoffs.** The content of these statements addresses PST ability to understand design tradeoffs.	understand the design tradeoffs of an engineering problem.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Disciplinary Core Ideas	P16 S Sec1QA	Situations should be relevant, observable, and specific and apply DCIs in the life, earth and physical sciences. For example, if a lake has dying fish...this is the situation/scenario. Students would need to apply their **understanding** of the **DCIs** to define what is causing the fish to die, i.e... chemicals, food web? Or if it is too hot in the room, students would need to decide what is causing the discomfort, i.e... lack of ventilation, shade, personal preference.	Panel members used the statements **understand and DCIs**. The content of these statements addresses PST ability to understand Disciplinary Core Ideas.	understand Disciplinary Core Ideas.
Understand Engineering as a Process	P2 T Sec1QA	Must **understand** the '**engineering process**'	Panel members used the statements **understand, and engineering design process.** The content of these statements addresses PST ability to understand engineering as a process.	understand engineering as a process.
	P3 T Sec1QA	They must **know** the **engineering design process** is used in engineering and technology		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
	P4 T Sec1QA	Articulate **engineering problems** in a way that implies knowledge of engineering practices.		
	P6 T Sec1QA	**Understanding** that **engineering** is both a technological **process** as well as a professional discipline.		
	P7 T Sec1QA	**Understand** the **engineering design process** and various models of the engineering design process.		
Understand Engineering Problems	P13 T Sec1QA	**Understand** what an **engineering problem** "is"	The panel member used the statements **understand and engineering problem.** The content of these statements addresses PST ability to understand engineering problems.	understand engineering problems.
Understand Framework for K-12 Science Education	P16 S Sec1QA	**Understanding** of the shifts in the NGSS as indicated in the **Framework for K-12 Science Education.**	The panel member used the statements **understand and Framework for K-12 Science Education**. The content of these statements addresses PST ability to understand the Framework for K-12 Science Education.	understand the Framework for K-12 Science Education.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand How to Teach Engineering Practices	P12 S Sec1QA	They should experience content embedded engineering activities, should understand how to **teach** content as well as **engineering practices**.	The panel member used the statement **teach engineering practices.** The content of these statements addresses PST ability to understand how to teach engineering practices.	understand how to teach engineering practices.
Understand How to Teach Science Content	P12 S Sec1QA	They should experience content embedded engineering activities, should **understand** how to **teach content** as well as engineering practices.	The panel member used the statements **understand and teach content.** The content of these statements addresses PST ability to understand how to teach science content.	understand how to teach science content.
Understand NGSS	P16 S Sec1QA	**Understanding** of the shifts in the **NGSS** as indicated in the Framework for K-12 Science Education.	The panel member used the statements **understanding and NGSS** The content of these statements addresses PST ability to understand the NGSS.	understand the shifts in NGSS as indicated in the Framework of K-12 Science Education.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Scientific Inquiry	P8 S Sec1QA	Teachers must be able to **understand** and define **inquiry,** scientific processes and computational thinking.	The panel member used the statements **understand and scientific inquiry.** NGSS The content of these statements addresses PST ability to understand scientific inquiry.	understand scientific inquiry.
Understand the Vocation of Engineering	P3 T Sec1QA	**Engineering applies** math and science to create technology.	Panel members used the statements **applies, engineering, fields, and jobs**. The content of these statements addresses PST ability understand the vocation of engineering.	understand the vocation of engineering.
	P6 T Sec1QA	**Recognize** that there are several **engineering fields** that focus on specific issues.		
	P12 S Sec1QA	Have to understand what **engineers** do in their **jobs** and the diversity of engineering jobs.		
	P13 T Sec1QA	**Understand** the **field** of **engineering** and how engineering problems are different from experimental problems.		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Utilize Educational Standards	P4 T Sec1QA	Identify the critical content and skills objectives of a **standard** in order to intentionally focus the **development** of engineering problems during a lesson.	Panel members used the statements **standard, development, apply, focus, and state curriculum standards.** The content of these statements addresses PST ability to utilize educational standards.	utilize educational standards in the development of engineering problems.
	P19 S Sec1QA	**Apply** Design, Engineering and Technology Literacy **Standards** content knowledge and skills to the designing and implementation of DTE learning activities.		
	P19 S Sec1QA	Implement and analyze STEM learning experiences regarding their **focus** on **State Curriculum Standards** for Mathematics, Science, Technology, and Engineering–Grades K-8 (MSDE)		

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Utilize Iterative Design Process	P15 T Sec1QA	**Solve problems** related societal needs **utilizing an iterative design**/problem solving **process**.	The panel member used the statements **solve problems and utilizing an iterative design.** The content of these statements addresses PST ability to utilize an iterative design to solve problems.	utilize an iterative design process to solve societal problems.
Utilize Real World Examples	P3 T Sec1QA	Solve open-ended **real-world problems**.	Panel members used the statements **solve, situate, provide examples, societal and real word.** The content of these statements addresses PST ability to utilize and provide real world examples	utilize real world examples when solving engineering design problems.
	P5 S Sec1QA	Teachers must be able to **situate problems** within an authentic **real-world** context.		
Utilize Tools and Instruments	P6 T Sec1QA	They must sacrifice some of their science preparation for engineering courses so that they would have some of the pre-requisite skills, like **working** with **testing equipment; general tools and machines,** and so forth.	Panel members used the statements **working with, demonstrate, testing equipment and tools.** The content of these statements addresses PST ability to utilize engineering tools and instruments.	utilize engineering tools and instruments.

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
	P20 T Sec1QA	**Demonstrate** safe **use** of **tools.**		

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Administering Problem-Based Activities	P15 T Sec1QB	**Carry out** the process for **solving a problem.**	The panel member used the statements **carry out and solving a problem.** The content of these statements addresses how teacher educators should engage their students in administering problem-based activities.	administering problem-based engineering activities.
Analyzing Case Studies	P11 T Sec1QB	Use (review, **analyze,** discuss) **case studies.**	The panel member used the statements **analyze and case studies.** The content of these statements addresses how teacher educators should engage their students in analyzing case studies.	analyzing engineering case studies.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Applying Engineering Concepts	P3 T Sec1QB	They should be able to develop a project-based learning (PBL) activity/lesson that requires student to **apply** both scientific and **engineering concepts** and practices	The panel member used the statements **apply and engineering concepts.** The content of these statements addresses how teacher educators should engage their students in applying engineering concepts.	developing problem-based learning activities and lessons that require students to apply engineering concepts.
Applying Engineering Practices	P3 T Sec1QB	They should be able to develop a project-based learning (PBL) activity/lesson that requires student to **apply** both scientific and **engineering** concepts and **practices**	The panel member used the statements **apply, engineering and practices**. The content of these statements addresses how teacher educators should engage their students in applying engineering practices.	developing problem-based learning activities and lessons that require students to apply engineering practices.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Applying Engineering Practices	P10 S Sec1QB	Pre-service teachers should **experience** situations where they are exposed to problems that **require** an **engineering-type solution** and those that don't (so that they can tell the **difference**).	The panel member used the statements **require engineering, and solutions.** The content of these statements addresses how teacher educators should engage their students in applying engineering practices.	applying engineering practices.
Applying Scientific Concepts	P3 T Sec1QB	They should be able to develop a project-based learning (PBL) activity/lesson that requires student to **apply** both **scientific** and engineering **concepts** and practices	The panel member used the statements **apply, scientific and concepts**. The content of these statements addresses how teacher addresses how teacher educators should engage their students in applying scientific concepts.	developing problem-based learning activities and lessons that require students to apply scientific concepts.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Applying Scientific Practices	P3 T Sec1QB	They should be able to develop a project-based learning (PBL) activity/lesson that requires student to **apply** both **scientific** and engineering concepts and **practices**	The panel member used the statements apply, scientific and practices. The content of these statements addresses how teacher educators should engage their students in applying scientific practices.	developing problem-based learning activities and lessons that require students to apply scientific practices.
Authentic Engineering Activities	P13 T Sec1QB	**Create practical connections** to the student's life experiences through examples of **engineered products** and how they meet defined problems.	The panel member used the statements **create practical connections and products**. The content of these statements addresses how teacher educators should engage their students in authentic engineering activities.	creating authentic engineering activities.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Authentic Science Activities	P5 S Sec1QB	Engaging students in **authentic**, active **science experiences** that force them to consider both isolated and contextualized scientific phenomena and determine whether they involve a problem of engineering or design.	The panel member used the statements **authentic and science experiences**. The content of these statements addresses how teacher educators should engage their students in authentic science activities.	creating authentic science activities.
Brainstorming Engineering Activities	P16 S Sec1QB	They need to **brainstorm** engage scenarios/situations that present students with opportunities to define problems.	The panel member used the statement **brainstorm.** The content of these statements addresses how teacher educators should engage their students in brainstorming engineering activities.	brainstorming engineering activities.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Building Technical Devices	P15 T Sec1QB	Manage a project in designing and **building a technical device** that solves a problem.	Panel members used the statements and The content of these statements **building a technical device, modeling and build models.** addresses how teacher educators should engage their students in building technical devices/models.	designing and building a technical device that solves an engineering problem.
Building Technical Models	P15 T Sec1QB	**Modeling** and prototype development.	Panel members used the statements and The content of these statements **building a technical device, modeling and build models.** addresses how teacher educators should engage their students in building technical devices/models.	designing and building a model or prototype that solves an engineering problem.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
	P16 S Sec1QB	Teachers also struggle with the concept of constraints...they think it is about available materials or class time to **build models** of possible solutions...rather than what would constrain the solution designs themselves.	Panel members used the statements and The content of these statements **building a technical device, modeling and build models.** addresses how teacher educators should engage their students in building technical devices/models.	
Collaborative Analysis of Engineering Design Resources	P16 S Sec1QB	Teacher educators should engage pre-service teachers in **collaborative analysis** and critique of engage design **resources** available online and manufacturers. Pre-service teachers need to be critical consumers of what is available because very little engages students in defining the problem (most give students a challenge).	Panel members used the statements **collaborative analysis, critique, design and resources.** The content of these statements addresses how teacher educators should engage their students in collaborative analysis of engineering design resources.	collaborative analysis of engineering design resources.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Collaborative Analysis of Engineering Design Resources	P16 S Sec1QB	Teacher educators should engage pre-service teachers in **collaborative** analysis and **critique of** engage **design resources** available online and manufacturers. Pre-service teachers need to be critical consumers of what is available because very little engages students in defining the problem (most give students a challenge).	Panel members used the statements **collaborative analysis, critique, design and resources.** The content of these statements addresses how teacher educators should engage their students in collaborative analysis of engineering design resources.	collaborative critique of engineering design resources.
Collaborative Learning Activities	P14 T Sec1QB	Encourage Team Work – Encourage all students to work **collaboratively** in **teams,** and share ideas and resources with peers.	The panel member used the statements **collaboratively and teams.** The content of these statements addresses how teacher educators should engage their students in collaborative learning activities.	collaborative engineering design activities.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Collaboratively Align Lessons to the NGSS	P16 S Sec1QB	Teacher educators must communicate that revising lessons/units to **align with NGSS** must be a **collaborative process** with ES, PS and LS teachers. If is very difficult for one teacher, in isolation, to align lessons. "	The panel member used the statements **align with NGSS and collaborative process.** The content of these statements addresses how teacher educators should engage their students in collaboratively aligning lessons to the NGSS.	collaboratively aligning science and engineering lessons to the NGSS.
Comparing and Contrasting the Science Approach vs. Engineering Approach to Solve a Problem	P17 S Sec1QB	Examine scenarios where science solved a problem and engineering solved the same problem--**compare and contrast the two approaches.**	Panel members used the statements **compare and contrast the two approaches and compare and contrast science and engineering models.** The content of these statements addresses how teacher educators should engage their students in comparing and contrasting the science approach to the engineering approach in order to solve a problem.	comparing and contrasting the science approach to the engineering approach in order to solve the same problem.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Comparing and Contrasting the Science Approach vs. Engineering Approach to Solve a Problem	P17 S Sec1QB	**Compare and contrast science and engineering models.**	Panel members used the statements **compare and contrast the two approaches and compare and contrast science and engineering models.** The content of these statements addresses how teacher educators should engage their students in comparing and contrasting the science approach to the engineering approach in order to solve a problem.	comparing and contrasting science and engineering models.
Computational Thinking Activities	P8 S Sec1QB	Teacher educators should engage pre-service teachers in activities that require them to make models to **engage** in inquiry, scientific processes, and **computational thinking** for themselves.	The panel member used the statements **engage and computational thinking.** The content of these statements addresses how teacher educators should engage their students in computational thinking activities.	computational thinking science activities.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Conducting Curriculum Inventories to Identify Potential Areas to Utilize Engineering Design	P11 T Sec1QB	**Conduct curriculum inventories** to **identify areas** that might lend themselves well **to use of engineering design**	The panel member used the statements **conduct curriculum inventories; identify areas, to use engineering design.** The content of these statements addresses how teacher educators should engage their students in conducting curriculum inventories to identify potential areas to utilize engineering design.	conducting curriculum inventories to identify potential areas to utilize engineering design.
Contextualizing Scientific Phenomena	P5 S Sec1QB	Engaging students in authentic, active science experiences that force them to consider both isolated and **contextualized scientific phenomena** and determine whether they involve a problem of engineering or design.	The panel member used the statement contextualized scientific phenomena. The content of these statements addresses how teacher educators should engage their students in contextualizing scientific phenomena.	contextualizing scientific phenomena to determine whether it involves a problem of engineering design.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Cooperative Learning Strategies	P12 S Sec1QB	Should learn **cooperative learning** strategies, group discourse tools and inquiry (data collection and analysis) as well as argumentation skills"	The panel member used the statements **cooperative learning** The content of these statements addresses how teacher educators should engage their students in cooperative learning activities.	cooperative learning activities.
Defining Engineering Problems	P1 T Sec1QB	Project-based instruction with opportunities to practice **defining engineering problems.**	Panel members used the statements **define and engineering problems**. The content of these statements addresses how teacher educators should engage their students in defining engineering problems.	defining engineering problems.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
	P5 S Sec1QB	Presenting students with scientific phenomena, model or experience and asking them to identify and **define** both the scientific questions and the **engineering problems** related to those observations.	Panel members used the statements **define and engineering problems**. The content of these statements addresses how teacher educators should engage their students in defining engineering problems.	
	P11 T Sec1QB	Engage pre-service teachers in guided activities involving **defining engineering problems**	Panel members used the statements **define and engineering problems**. The content of these statements addresses how teacher educators should engage their students in defining engineering problems.	

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
	P13 T Sec1QB	Practice **defining problems -** new and old problems.	Panel members used the statements **define and engineering problems**. The content of these statements addresses how teacher educators should engage their students in defining engineering problems.	
Defining Scientific Questions	P5 S Sec1QB	Presenting students with scientific phenomena, model or experience and asking them to identify and **define** both the **scientific questions** and the engineering problems related to those observations.	The panel member used the statements **define and scientific questions.** The content of these statements addresses how teacher educators should engage their students in defining scientific questions.	defining scientific questions.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Demonstrating Difference Between Scientific Inquiry and Engineering Design	P7 T Sec1QB	Understand and distinctly **demonstrate** the **difference** between **engineering design and scientific inquiry.**	The panel member used the statements **demonstrate, difference, engineering design, and scientific inquiry**. The content of these statements addresses how teacher educators should engage their students in demonstrating difference between scientific inquiry and engineering design.	demonstrating the difference between scientific inquiry and engineering design.
Demonstrations of Laboratory Practices Used in Technology and Engineering	P3 T Sec1QB	They should be able to give effective classroom and **laboratory demonstration** on practices **used in technology and engineering.** This activity will require them to learn basic concepts and practices used in engineering.	The panel member used the statements **laboratory demonstration, used in technology and engineering**. The content of these statements addresses how teacher educators should engage their students in demonstrations of laboratory practices used in technology and engineering.	demonstrations of laboratory practices used in technology and engineering.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Demonstrating Researching Procedures	P20 T Sec1QB	**Demonstrate** ethical **research procedures.**	The panel member used the statements **demonstrate, research procedures.** The content of these statements addresses how teacher educators should engage their students in demonstrating research procedures.	demonstrating ethical research procedures.
Describing the Purpose of Integrative STEM	P3 T Sec1QB	I believe these pre-service teachers should be able to **describe the purpose of integrative STEM Education**	The panel member used the statement describe the purpose of integrative STEM education. The content of these statements addresses how teacher educators should engage their students in describing the purpose of integrative STEM education.	describing the purpose of integrative STEM education.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Design-Based Lesson Model Practices for in NGSS	P16 S Sec1QB	Teacher educators should engage pre-service teachers in engage **design lesson**s to **model** the learning and intent of defining the problem in the **NGSS**.	The panel member used the statements design lessons, model and NGSS. The content of these statements addresses how teacher educators should engage their students in design-based lessons to modeling the practices identified in the NGSS.	design-based lessons to modeling the practices identified in the NGSS.
Design-Based Pedagogical Approaches	P3 T Sec1QB	(i.e., "the application of technological/engineering **design-based pedagogical approaches** to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education”).	The panel member used the statement **design-based pedagogical approaches.** The content of these statements addresses how teacher educators should engage their students in design-based pedagogical approaches.	design-based pedagogical approaches intentionally to teach the content and practices of science and mathematics education through the content and practices of technology/engineering education.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Designing Age & Grade Appropriate Goals	P14 T Sec1QB	Plan and adapt lessons – Set **appropriate learning goals,** adjust curricula and use inquiry/design-based instructional models (e.g., 5E, informed design) to create lessons that address students' specific learning needs.	The panel member used the statement **appropriate learning goals.** The content of these statements addresses how teacher educators should engage their students in designing age & grade appropriate learning goals.	designing age and grade appropriate inquiry/design based instructional models.
Designing Lessons	P6 T Sec1QB	**Lesson planning**	The panel member used the statement **lesson planning.** The content of these statements addresses how teacher educators should engage their students in designing lessons.	designing hands-on problem solving lessons in science and engineering.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Designing Technical Devices	P15 T Sec1QB	Manage a project in **designing** and building a **technical device** that solves a problem.	The panel member used the statement **designing and technical device**. The content of these statements addresses how teacher educators should engage their students in designing technical devices.	designing technical devices to solve engineering problems.
Determining to Involve Engineering Design in Science Problems	P5 S Sec1QB	Engaging students in authentic, active science experiences that force them to consider both isolated and contextualized scientific phenomena and **determine** whether they **involve** a problem of **engineering** or **design.**	The panel member used the statements determine, involve and engineering. The content of these statements addresses how teacher educators should engage their students in determining to involve engineering design in science problems.	determining to involve engineering design in science problems.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Developing Knowledge of Technical Skills	P6 T Sec1QB	General **technical skills and knowledge.**	The panel member used the statements **technical skills and knowledge.** The content of these statements addresses how teacher educators should engage their students in developing knowledge of technical skills.	developing knowledge of technical skills.
Developing Problem Statements	P15 T Sec1QB	Practice in **developing** clear **problem statements**.	The panel member used the statements **developing and problem statements**. The content of these statements addresses how teacher educators should engage their students in developing problem statements.	developing technological problem statements.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Developing Problem-Based Learning Activities	P3 T Sec1QB	They should be able to **develop** a **project-based learning** (PBL) **activity/lesson** that requires student to apply both scientific and engineering concepts and practices	The panel member used the statement develop a project-based learning activity/lesson. The content of these statements addresses how teacher educators should engage their students in developing problem-based learning activities.	developing problem-based learning activities that require students to apply both scientific and engineering concepts and practices.
Development of Engineering Design Challenges	P3 T Sec1QB	They should be able to **develop** an **"engineering design challenge"** that identifies a technology/engineering type problem to solve, including criteria and constraints associated with that problem.	The panel member used the statement **develop an engineering design challenge.** The content of these statements addresses how teacher educators should engage their students in development of engineering design challenges.	development of engineering design challenges.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Differentiating Between Scientific Inquiry and Engineering Design	P3 T Sec1QB	They should be able to clearly describe how **engineering and science concepts** and practices are similar, and **different.**	Panel members used the statements **engineering and science concepts, different, determine, between scientific questions and engineering, understand, design, and inquiry**. The content of these statements addresses how teacher educators should engage their students in differentiating between scientific inquiries and engineering design.	differentiating between scientific inquiries and engineering design.
Differentiating Between Scientific Inquiry and Engineering Design	P5 S Sec1QB	Engaging students in inquiry and modeling experiences that require them to **determine** the **difference between scientific questions and engineering problems,** and how they work together to form a complete understanding of science principles and their application.	Panel members used the statements **engineering and science concepts, different, determine, between scientific questions and engineering, understand, design, and inquiry**. The content of these statements addresses how teacher educators should engage their students in differentiating between scientific inquiries and engineering design.	determining the difference between scientific inquiry and engineering design.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Differentiating Between Scientific Inquiry and Engineering Design	P7 T Sec1QB	Understand and distinctly **demonstrate** the **difference** between **engineering design and scientific inquiry**.	Panel members used the statements **demonstrate, difference, engineering design and scientific inquiry**. The content of these statements addresses how teacher educators should engage their students in differentiating between scientific inquiries and engineering design.	demonstrating the difference between scientific inquiry and engineering design.
Differentiating Problem Based Learning and Project Based Learning	P2 T Sec1QB	understand the **difference** between **problem based learning and project based learning**	The panel member used the statements **difference and problem based learning and project based learning.** The content of these statements addresses how teacher educators should engage their students in differentiating problem based learning and project based learning.	differentiating problem based learning and project based learning.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Discussing Case Studies	P11 T Sec1QB	Use (review, analyze, **discuss**) **case studies.**	The panel member used the statements **discuss and case studies**. The content of these statements addresses how teacher educators should engage their students in discussing case studies.	discussing engineering case studies.
Discussing Concepts of the NGSS	P19 S Sec1QB	Discussion- engaging students in **discussions surrounding** the **concepts of NGSS** and the integration of subjects as well as how the engineering design practices should be embedded within the curriculum	The panel member used the statements **discussions surrounding the concepts of NGSS.** The content of these statements addresses how teacher educators should engage their students in discussing concepts of the NGSS.	discussing concepts of the NGSS and how engineering design practices should be embedded within the curriculum.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Discussions Between Peers of the K-12 Science Framework	P16 S Sec1QB	Pre-service teachers must read the **Framework** and **discuss** with **colleagues** the research that drives the conceptual shifts.	The panel member used the statements **Framework, discuss, colleagues**. The content of these statements addresses how teacher educators should engage their students in peer discussions of the K-12 Science Framework.	peer discussions on the conceptual shifts of K-12 Science Framework.
Distinguishing Engineering Problems	P20 T Sec1QB	**Distinguish problems** that require engineering solutions.	The panel member used the statement distinguish problems. The content of these statements addresses how teacher educators should engage their students in distinguishing engineering problems.	distinguishing science problems that require engineering solutions.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Documenting Engineering Design Solutions	P3 T Sec1QB	They should learn about keeping and engineering notebook that is used to **document** the **solving** of an **engineering design** problem	The panel member used the statements **document, solve, problem and engineering design.** The content of these statements addresses how teacher educators should engage their students in documenting engineering design solutions.	documenting engineering design solutions.
Documenting Engineering Design Solutions	P15 T Sec1QB	Develop a design portfolio **documenting** the process for **solving a problem.**	The panel member used the statements **document, solve, problem and engineering design**. The content of these statements addresses how teacher educators should engage their students in documenting engineering design solutions.	documenting engineering design solutions.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Embracing Ambiguity	P18 T Sec1QB	Teachers should: **embrace ambiguity**, be willing to say, "I don't know", guide students towards understanding a problem, teach methods that lend toward innovation and not just recreation.	The panel member used the statement **embrace ambiguity.** The content of these statements addresses how teacher educators should engage their students in embracing ambiguity.	embracing ambiguity and guiding students towards an understanding of a problem.
Hands-on Design Activities	P6 T Sec1QB	**Hands-on design activities.**	The panel member used the statement **hands-on design activities**. The content of these statements addresses how teacher educators should engage their students in hands-on design activities.	hands-on engineering design activities.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Hands-on Problem Solving Activities	P6 T Sec1QB	**Hands-on problem solving activities.**	The panel member used the statement **hands-on problem solving activities**. The content of these statements addresses how teacher educators should engage their students in hands-on problem solving activities.	hands-on problem solving activities.
Identification of Technological/Engineering Constraints	P3 T Sec1QB	They should be able to develop an "engineering design challenge" that **identifies a technology/engineering** type problem to solve, including criteria and **constraints** associated with that problem.	The panel member used the statement i**dentifies a technology/engineering and constraints.** The content of these statements addresses how teacher addresses how teacher educators should engage their students in identifying technological/engineering constraints.	identifying the technological/engineering constraints of engineering problem.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Identification of Technological/Engineering Criteria	P3 T Sec1QB	They should be able to develop an "engineering design challenge" that **identifies a technology/engineering** type problem to solve, including **criteria** and constraints associated with that problem.	The panel member used the statements **identifies a technology/engineering and criteria.** The content of these statements addresses how teacher educators should engage their students in identifying technological/engineering criteria.	identifying the technological/engineering criteria of an engineering problem.
Identification of Technological/Engineering Type Problems	P3 T Sec1QB	They should be able to develop an "engineering design challenge" that **identifies** a **technology/engineering type problem** to solve, including criteria and constraints associated with that problem.	The panel member used the statement **identifies a technology/engineering type problem**. The content of these statements addresses how teacher educators should engage their students in identifying technological/engineering criteria.	identifying technological/engineering problems.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Identifying Design Constraints	P16 S Sec1QB	Teachers also struggle with the concept of **constraint**s...they think it is about available materials or class time to build models of possible solutions...rather than what would **constrain the solution designs** themselves.	The panel member used the statements **constraints, and constrains the solution design.** The content of these statements addresses how teacher educators should engage their students in identifying design constraints.	identifying design constraints due to available materials or class time.
Identifying Engineering Problems	P5 S Sec1QB	Presenting students with scientific phenomena, model or experience and asking them to **identify** and define both the scientific questions and the **engineering problems** related to those observations.	The panel member used the statements **identify, require engineering, and problem.** The content of these statements addresses how teacher educators should engage their students in identifying engineering problems.	identifying engineering problems.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Identifying Science Questions	P5 S Sec1QB	Presenting students with scientific phenomena, model or experience and asking them to **identify** and define both the **scientific questions** and the engineering problems related to those observations.	The panel member used the statements **identify and scientific questions.** The content of these statements addresses how teacher educators should engage their students in identifying science questions.	identifying science questions.
Identifying the Vocation of Engineering	P11 T Sec1QB	Know what **engineers do** and experience hands on content based engineering design challenge activities in their content area (bio, Chemistry, physics).	The panel member used the statements **engineers and does.** The content of these statements addresses how teacher educators should engage their students in identifying the vocation of engineering.	identifying the vocation of engineering.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Interdisciplinary Teams	P11 T Sec1QB	Use **interdisciplinary teams** of STEM (or beyond) pre-service teachers	The panel member used the statement **interdisciplinary teams.** The content of these statements addresses how teacher educators should engage their students in interdisciplinary teams.	interdisciplinary STEM teams to solve engineering problems.
Introduce Educational Resources	P16 S Sec1QB	Teacher educators need to **introduce** pre-service teachers to the **resources a**vailable by NSTA and others that are research based in support of the NGSS and engage design.	The panel member used the statements **introduce and resources.** The content of these statements addresses how teacher educators should engage their students in introducing educational resources.	introducing educational resources such as the NGSS.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Isolating Scientific Phenomena	P5 S Sec1QB	Engaging students in authentic, active science experiences that force them to consider both **isolated** and contextualized **scientific phenomena** and determine whether they involve a problem of engineering or design.	The panel member used the statements **isolated and scientific phenomena.** The content of these statements addresses how teacher educators should engage their students in considering isolated scientific phenomena.	isolated scientific phenomena to determine if it involves engineering design problem.
Keeping a Journal	P16 S Sec1QB	Pre-service teachers could **keep a journal** of their questions, their learning and their successes.	The panel member used the statement **keep a journal.** The content of these statements addresses how teacher educators should engage their students in keeping a journal.	keeping a journal.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Lesson Facilitation	P2 T Sec1QB	the role of the teacher is to be a **facilitator** - not a lecturer	Panel members used the statement **facilitator**. The content of these statements addresses how teacher educators should engage their students in lesson facilitation.	facilitated science and engineering lessons.
Lesson Facilitation	P4 T Sec1QB	Teachers must function as **facilitators** of student learning.	Panel members used the statement **facilitator**. The content of these statements addresses how teacher educators should engage their students in lesson facilitation.	facilitated science and engineering lessons.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Making Connections Between Science and Engineering Concepts	P4 T Sec1QB	Teachers must be able to **make connections between science and engineering** concepts and practices.	The panel member used the statement **make connections between science and engineering concepts.** The content of these statements addresses how teacher educators should engage their students in making connections between science and engineering concepts.	making connections between science and engineering concepts.
Making Connections Between Science and Engineering Practices	P4 T Sec1QB	Teachers must be able to **make connections between science and engineering** concepts and **practices**.	The panel member used the statement **make connections between science and engineering practices.** The content of these statements addresses how teacher educators should engage their students in making connections between science and engineering practices.	making connections between science and engineering practices.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Making Models	P8 S Sec1QB	Teacher educators should engage pre-service teachers in activities that require them to **make models** to engage in inquiry, scientific processes, and computational thinking for themselves.	The panel member used the statement make models between science and engineering practices. The content of these statements addresses how teacher educators should engage their students in making models.	making scientific models.
Modeling Utilization of Materials	P19 S Sec1QB	**Demonstrations** of how **various material**s and/or activities can be **utilized** in the curriculum.	The panel member used the **statements demonstrations, various materials and utilized.** The content of these statements addresses how teacher educators should engage their students in modeling the utilization of materials.	modeling the utilization of science materials.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Modeling Inquiry Practices	P5 S Sec1QB	The use of **inquiry practices** and **modeling** to engage students in the scientific process, including both scientific and engineering practices.	The panel member used the statements **inquiry practices and modeling.** The content of these statements addresses how teacher educators should engage their students in modeling inquiry practices.	modeling scientific inquiry practices.
Modeling Safe Tool Use	P20 T Sec1QB	**Model** safe **use** of tools.	The panel member used the statements **model and safe**. The content of these statements addresses how teacher educators should engage their students in modeling safe tool use.	modeling safe technology and engineering tool use.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Open-Ended, Multiple Solution Problems	P4 T Sec1QB	Teachers must be able to allow for and encourage **open-ended, multiple solution problems.**	The panel member used the statements **open-ended, multiple solution problems**. The content of these statements addresses how teacher educators should engage their students in open-ended, multiple solution problems.	open-ended, multiple solution engineering problems.
Participating in Lesson as Students	P16 S Sec1QB	Pre-service teachers need to **participate as students** to understand the grade level student performance expectation differences.	The panel member used the statements **participate as students.** The content of these statements addresses how teacher educators should engage their students in participating in lessons as students.	participating in science lessons as students.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Peer Evaluations	P5 S Sec1QB	**Peer evaluation** of curriculum ideas related to getting students to define engineering problems.	The panel member used the statement **peer evaluation.** The content of these statements addresses how teacher educators should engage their students in peer evaluations.	peer evaluations of curriculum focused on the defining of engineering problems.
Practicing Project Based Learning Challenges	P2 T Sec1QB	**Practice** using **Problem Based Learning** challenges to help determine what engineering practices are appropriate to their topic	The panel member used the statement **practice, problem based learning**. The content of these statements addresses how teacher educators should engage their students in practicing project based learning challenges.	practicing project based engineering learning challenges.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Presentations on Scientific Phenomena	P5 S Sec1QB	**Presenting** students with **scientific phenomena,** model or experience and asking them to identify and define both the scientific questions and the engineering problems related to those observations.	The panel member used the statements **presenting and scientific phenomena.** The content of these statements addresses how teacher educators should engage their students in presentations on scientific phenomena.	presentations on scientific phenomena.
Presentations Using Scientific Experiences	P5 S Sec1QB	**Presenting** students with scientific phenomena, model or **experience** and asking them to identify and define both the scientific questions and the engineering problems related to those observations.	The panel member used the statements **presenting and experience**. The content of these statements addresses how teacher educators should engage their students in presentations using scientific experiences.	presentations using scientific experiences.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Presentations Using Scientific Models	P5 S Sec1QB	**Presenting** students with **scientific** phenomena, **model** or experience and asking them to identify and define both the scientific questions and the engineering problems related to those observations.	The panel member used the statements **presenting, scientific, and model**. The content of these statements addresses how teacher educators should engage their students in presentations using scientific models.	presentations using scientific models.
Problem Based Learning Activities	P8 S Sec1QB	Unless they actually **do** the **exercises** that they require students to do, pre-service teachers will not fully understand the learning curve and the skills that students need to solve engineering problems and participate in engineering tasks.	The panel member used the statements **do, exercises, problem based learning.** The content of these statements addresses how teacher educators should engage their students in problem based learning activities.	problem based engineering activities.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Problem Based Learning Activities	P9 S Sec1QB	**Problem Based Learning**	The panel member used the statements **do, exercises, problem based learning.** The content of these statements addresses how teacher educators should engage their students in problem based learning activities.	problem based engineering activities.
Project Based Instruction	P7 T Sec1QB	**Immerse** them in a true **engineering design problem** task so they can experience the engineering design process.	The panel member used the statements **immerse, engineering design problem and project-based instruction.** The content of these statements addresses how teacher educators should engage their students in project based instruction.	design based engineering instruction.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Project Based Instruction	P1 T Sec1QB	**Project-based instruction** with opportunities to practice defining engineering problems.	The panel member used the statements **immerse, engineering design problem and project-based instruction.** The content of these statements addresses how teacher educators should engage their students in project based instruction.	project based engineering instruction.
Prototype Development	P15 T Sec1QB	Modeling and **prototype development.**	The panel member used the statements **prototype development.** The content of these statements addresses how teacher educators should engage their students in prototype development.	developing engineering prototypes.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Providing Feedback to Students	P14 T Sec1QB	Use Formative Assessments – Use formative assessments to gather evidence of students' learning, **provide timely feedback**, and adjust daily instruction.	The panel member used the statement **provide timely feedback**. The content of these statements addresses how teacher educators should engage their students in providing feedback to K-12 students.	providing feedback to K-12 students.
Reading the K-12 Science Framework	P16 S Sec1QB	Pre-service teachers **must read the Framework** and discuss with colleagues the research that drives the conceptual shifts.	The panel member used the statement **must read the Framework.** The content of these statements addresses how teacher educators should engage their students in reading the K-12 science framework.	reading the K-12 science Framework.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Reflecting on Environment, Safety, Economical, and Human Impact Constraints	P17 S Sec1QB	Draw or **reflect** on safety, **economics, and human impact** as part of the **constraints** of the problem.	The panel member used the statements **reflect, economics, human impact and constraints**. The content of these statements addresses how teacher educators should engage their students in reflecting on the environmental safety, economical and human impact constraints.	reflecting on the environmental safety, economical, and human impact constraints of a science problem.
Researching Engineering Design Process	P7 T Sec1QB	Require pre-service teachers to **research** multiple versions of the **engineering design process.**	The panel member used the statements **research and engineering design process.** The content of these statements addresses how teacher educators should engage their students in researching engineering design processes.	researching the engineering design processes.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Reviewing Case Studies	P11 T Sec1QB	Use (**review,** analyze, discuss) **case studies.**	The panel member used the statements **review and case studies**. The content of these statements addresses how teacher educators should engage their students in reviewing case studies.	reviewing engineering case studies.
Scientific Inquiry Activities	P8 S Sec1QB	Teacher educators should engage pre-service teachers in activities that require them to make models to **engage in inquiry, scientific processes**, and computational thinking for themselves.	Panel members used the statements engage in **inquiry, scientific processes and based learning.** The content of these statements addresses how teacher educators should engage their students in scientific inquiry activities.	scientific inquiry activities.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Scientific Inquiry Activities	P9 S Sec1QB	**Inquiry Based Learning**	Panel members used the statements engage in **inquiry, scientific processes and based learning.** The content of these statements addresses how teacher educators should engage their students in scientific inquiry activities.	scientific inquiry activities.
Teaching Mini Lessons	P5 S Sec1QB	**Teaching mini-lessons** to their peers to try out curriculum ideas related to defining engineering problems.	The panel member used the statement **teaching mini lesson**. The content of these statements addresses how teacher educators should engage their students in teaching mini lessons to their peers.	teaching mini engineering lessons to their peers.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Technological/Engineering Design Pedagogical Approaches	P3 T Sec1QB	(i.e., "the **application of technological/engineering** design-based **pedagogical approaches** to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education”).	The panel member used the statement **application of technological/engineering and pedagogical approaches**. The content of these statements addresses how teacher educators should engage their students in applying technological/engineering design pedagogical approaches.	applying technological/engineering design pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education.
Using Appropriate Instructional Strategies to Engage Students in Design-Processes	P14 T Sec1QB	When teaching engineering design, teachers use **appropriate instructional strategies to** engage all students in the design process and monitor their progress.	The panel member used the statements **appropriate and instructional strategies.** The content of these statements addresses how teacher educators should engage their students in using hands on learning experiences in using instructional strategies to engage students in the design-processes.	appropriate instructional strategies to engage students in the engineering design-processes.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Argumentation Skills	P12 S Sec1QB	Should learn cooperative learning strategies, group discourse tools and inquiry (data collection and analysis) as well as **argumentation skills"**	The panel member used the statement **argumentation skills**. The content of these statements addresses how teacher educators should engage their students in using argumentation skills.	using argumentation skills.
Using Case Studies	P9 S Sec1QB	Practice **Case Study** use in classroom settings.	The panel member used the statements **use and case studies**. The content of these statements addresses how teacher educators should engage their students in using case studies.	using case studies.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Case Studies	P11 T Sec1QB	**Use** (review, analyze, discuss) **case studies.**	The panel member used the statements **use and case studies**. The content of these statements addresses how teacher educators should engage their students in using case studies.	using case studies.
Using Data Analysis	P12 S Sec1QB	Should learn cooperative learning strategies, group discourse tools and inquiry (**data** collection and **analysis**) as well as argumentation skills"	The panel member used the statements **data and analysis.** The content of these statements addresses how teacher educators should engage their students in using data analysis.	using data analysis.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Data Collection	P12 S Sec1QB	Should learn cooperative learning strategies, group discourse tools and inquiry **(data collection** and analysis) as well as argumentation skills"	The panel member used the statement **data collection.** The content of these statements addresses how teacher educators should engage their students in using data collection.	using data collection.
Using Differentiated Instruction	P14 T Sec1QB	Plan and **adapt lessons** – Set appropriate learning goals, adjust curricula and use inquiry/design-based instructional models (e.g., 5E, informed design) to create lessons that address students' specific learning needs.	The panel member used the statement **adapt lessons**. The content of these statements addresses how teacher educators should engage their students in using differentiated instruction.	using differentiated instruction to teach engineering design.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Formative Assessments	P14 T Sec1QB	**Use Formative Assessments** – Use formative assessments to gather evidence of students' learning, provide timely feedback, and adjust daily instruction.	The panel member used the statement u**se formative assessments.** The content of these statements addresses how teacher educators should engage their students in using formative assessments.	using formative assessments to gather evidence of students' learning, provide timely feedback, and adjust daily instruction...
Using Group Discourse	P12 S Sec1QB	Should learn cooperative learning strategies, **group discourse** tools and inquiry (data collection and analysis) as well as argumentation skills"	The panel member used the statement **group discourse.** The content of these statements addresses how teacher educators should engage their students in using group discourse.	group discourse.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Hands on Learning Experiences with in Students Own Discipline	P12 S Sec1QB	Know what engineers do and experience **hands on** content based engineering design challenge activities **in their** content **area** (bio, Chemistry, physics).	The panel member used the statements **hands on and in their area**. The content of these statements addresses how teacher educators should engage their students in using hands on learning experiences in students own discipline.	using hands on learning experiences in students own discipline (bio, Chemistry, physics).
Using Instructional Strategies to Monitor Student Progress	P14 T Sec1QB	When teaching engineering design, teachers use appropriate **instructional strategies to** engage all students in the design process and **monitor** their progress.	The panel member used the statements **instructional strategies and monitor.** The content of these statements addresses how teacher educators should engage their students in using hands on learning experiences in using instructional strategies to monitor student progress.	using instructional strategies to monitor student progress of engineering design concepts.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Integrative Instructional Strategies	P14 T Sec1QB	**Support Integrative Learning** – incorporate literacy, numeracy, and technology tasks effectively in design-based instruction.	The panel member used the statement **support integrative learning.** The content of these statements addresses how teacher educators should engage their students in using hands on learning experiences in using integrative instructional strategies.	using integrative engineering design based instructional strategies.
Using Performance Rubrics	P14 T Sec1QB	Use Summative Assessments – **Use** assessments and **performance rubrics** to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.	The panel member used the statements **use and performance rubrics.** The content of these statements addresses how teacher educators should engage their students in using hands on learning experiences in using performance rubrics.	using performance rubrics to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Summative Assessments	P14 T Sec1QB	**Use Summative Assessments** – Use assessments and performance rubrics to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.	The panel member used the statements **use and summative assessments.** The content of these statements addresses how teacher educators should engage their students in using hands on learning experiences in using summative assessments.	using summative assessments to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.
Utilizing Concept Mapping	P6 T Sec1QB	**Conceptual Mapping.**	The panel member used the statement **conceptual mapping.** The content of these statements addresses how teacher educators should engage their students in utilizing concept mapping.	concept mapping.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing Cooperative Learning Activities	P19 S Sec1QB	**Cooperative learning**/group work- to ensure that there are a diverse set of skills present and so students can see how teams are vital to the success of an engineering project.	The panel member used the statement **cooperative learning.** The content of these statements addresses how teacher educators should engage their students in using hands on learning experiences in using cooperative learning activities.	cooperative learning activities so students can see how teams are vital to the success of an engineering project.
Utilizing Engineering Design Exemplars	P20 T Sec1QB	**Exhibit engineering design exemplars.**	The panel member used the statement **exhibit engineering design exemplars.** The content of these statements addresses how teacher educators should engage their students in utilizing engineering design exemplars.	utilizing engineering design exemplars.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing Media Presentations	P16 S Sec1QB	**Watching videos** of instruction is a good way to envision what should be happening.	The panel member used the statement **watching videos.** The content of these statements addresses how teacher educators should engage their students in utilizing media presentations.	media presentations of exemplary science and engineering instruction.
Utilizing Media Presentations	P19 S Sec1QB	**Media presentations**- both teacher educators and pre-service teachers alike should be utilizing technology to show examples of collaborative work skills in engineering design as well as to present their findings.	The panel member used the statements **media presentations and watching videos.** The content of these statements addresses how teacher educators should engage their students in utilizing media presentations.	media presentations of exemplary science and engineering instruction.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing Mini Lectures on Engineering Design Concepts and Other Subjects	P19 S Sec1QB	**Mini-lectures** to provide key information to teachers on engineering design concepts as well as additional subject matter that may be new to them.	The panel member used the statement **mini lectures**. The content of these statements addresses how teacher educators should engage their students in utilizing mini lectures on engineering design concepts and other subjects.	utilizing mini lectures on engineering design concepts and other subjects.
Utilizing Peer Sharing	P19 S Sec1QB	**Peer sharing-** pre-service teachers need to be able to teach these concepts to others as well as present their findings in an effective manner.	The panel member used the statement **peer sharing.** The content of these statements addresses how teacher educators should engage their students in utilizing peer sharing.	utilizing peer sharing to present findings in an effective manner.
Utilizing Science Content to Work Through Engineering Models	P17 S Sec1QB	**Work through engineering models using science content.**	The panel member used the statement **work through engineering models using science content.** The content of these statements addresses how teacher educators should engage their students in utilizing science content to work through engineering models.	utilizing science content to work through engineering models.

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Writing Lessons Focusing on Modeled Pedagogy	P5 S Sec1QB	**Writing lesson** plans that include the **pedagogy** they engaged in as students above.	The panel member used the statements **writing lesson and pedagogy.** The content of these statements addresses how teacher educators should engage their students in writing lessons focusing on modeled pedagogy.	writing lessons focusing on modeled pedagogy.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Ability Explain Problems in Written Form	P9 S Sec2QA	**Write**	The panel member used the statement **write.** The content of this statement addresses PST ability to explain problems in written form.	explain science problems in written form.
Ability to Analyze Design Solutions	P11 T Sec2QA	Knowledge of **strategies** for testing and **analyzing design solutions**	The panel member used the statements **strategies, and analyzing design solutions** The content of this statement addresses PST ability to analyze design solutions.	analyze engineering design solutions.
Ability to Analyze Data	P16 S Sec2QA	Pre-service teachers need to be able to **analyze data** and teach those strategies to their students.	The panel member used the statement analyze data The content of this statement addresses PST ability to analyze data.	analyze scientific data.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Ability to Choose an Engineering Design Solution	P14 T Sec2QA	Decide & Build – Balance benefits and tradeoffs in **choosing a solution** to build; use tools safely when making a prototype.	The panel member used the statement **choosing a solution.** The content of this statement addresses PST ability to choose an engineering design solution.	choose an engineering design solution.
Ability to do Hands on Activities	P4 T Sec2QA	Teachers must **provide opportunities** for **students** to engage in **hands-on,** prototyping activities.	The panel member used the statements **provide opportunities, students, and hands-on.** The content of this statement addresses PST ability to do hands on activities.	do hands on engineering prototyping activities.
Ability to Identify Multiple Solutions	P13 T Sec2QA	Should have creative capacities to **find solutions** to **problems.**	The panel member used the statements **find solutions and produces several**. The content of this statement addresses PST ability to identify multiple solutions.	identify multiple solutions to an engineering problem.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Ability to Identify Multiple Solutions	P14 T Sec2QA	Generate Alternatives – **Produce several** different possible design **solutions.**	The panel member used the statements **find solutions and produces several.** The content of this statement addresses PST ability to identify multiple solutions.	identify multiple solutions to an engineering problem.
Ability to Test Prototypes	P14 T Sec2QA	**Test Prototype** – Design and perform experiments to **test** how the **prototype** works and meets the design criteria.	The panel member used the statements **test prototype**. The content of this statement addresses PST ability to test prototypes.	design and test engineering prototypes.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Ability to Use Debugging to Solve Engineering Problems	P8 S Sec2QA	They must also persevere with **debugging** to solve engineering problems.	Panel members used the statements **computational thinking, higher order thinking skills and engineering.** The content of this statement addresses PST ability to apply logical thinking to design engineering activities.	utilize debugging to solve engineering problems.
Ability to Utilize Feedback.	P14 T Sec2QA	Revise & Iterate – **Use feedback** from tests and ideas from others to refine and improve the prototype iteratively.	The panel member used the statement use feedback. The content of this statement addresses PST ability to utilize feedback.	utilize feedback to refine engineering prototypes.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Adapt Prior Solutions	P1 T Sec2QA	Can I borrow or **adapt** previous **solutions** or technologies?	The panel member used the statements **adapt and solutions.** The content of this statement addresses PST ability to adapt prior solutions.	adapt prior engineering design solutions.
Adapt Prior Technologies	P1 T Sec2QA	Can I borrow or **adapt** previous solutions or **technologies?**	The panel member used the statements **adapt and technologies.** The content of this statement addresses PST ability to adapt prior technologies.	adapt prior technologies.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Add Additional Content	P1 T Sec2QA	Can I **add more** to the **problem** in an effort to find a solution?	The panel member used the statements **add more and problem.** The content of this statement addresses PST ability to add additional content.	add additional content to and engineering problem in an effort to find a solution.
Analyze STEM Learning Experiences	P19 S Sec2QA	Implement and **analyze STEM learning experiences** regarding their focus on State Curriculum Standards for Mathematics, Science, Technology, and Engineering–Grades K-8 (MSDE)	The panel member used the statements **analyze STEM learning experiences.** The content of this statement addresses PST ability to analyze STEM learning experiences.	analyze STEM learning experiences regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Apply Contextual Reading Skills	P9 S Sec2QA	**Read**	The panel member used the statements **read.** The content of this statement addresses PST ability to apply contextual reading skills.	apply contextual reading skills.
Apply Design, Engineering and Technology Literacy Standards	P19 S Sec2QA	**Apply Design, Engineering and Technology Literacy Standards** content knowledge and skills to the designing and implementation of DTE learning activities.	The panel member used the statement **apply design, engineering and technology literacy standards.** The content of this statement addresses PST ability to apply design, engineering and technology literacy standards.	apply design, engineering and technology literacy standards in the design and implementation of DTE learning activities.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Apply Logical Thinking to Design Engineering Task	P1 T Sec2QA	Can I do the **opposite** of what I am currently **thinking?**	Panel members used the statements **computational thinking, higher order thinking skills and engineering.** The content of this statement addresses PST ability to apply logical thinking to design engineering activities.	demonstrate logical thinking in the design of engineering activities.
Apply Logical Thinking to Design Engineering Task	P6 T Sec2QA	The ability to **think logically**.	Panel members used the statements **computational thinking, higher order thinking skills and engineering.** The content of this statement addresses PST ability to apply logical thinking to design engineering activities.	demonstrate logical thinking in the design of engineering activities.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Apply Logical Thinking to Design Engineering Task	P8 S Sec2QA	Teachers must understand how to use models, variables, and **computational thinking skills** to design an engineering task.	Panel members used the statements **computational thinking, higher order thinking skills, opposite thinking, think logically and engineering.** The content of this statement addresses PST ability to apply logical thinking to design engineering activities.	demonstrate logical thinking in the design of engineering activities.
Apply Logical Thinking to Design Engineering Task	P9 S Sec2QA	Recognize activities that foster **higher order thinking skills**	Panel members used the statements **computational thinking, higher order thinking skills and engineering.** The content of this statement addresses PST ability to apply logical thinking to design engineering activities.	demonstrate logical thinking in the design of engineering activities.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Apply STEM Pedagogical Concepts	P19 S Sec2QA	**Apply STEM pedagogical concepts**, in Design, Technology and Engineering Education in STEM focused curricular models.	The panel member used the statement **Apply STEM pedagogical concepts.** The content of this statement addresses PST ability to apply STEM pedagogical concepts.	apply STEM pedagogical concepts in design, technology and engineering education in STEM focused curricular models.
Augment Problems	P1 T Sec2QA	Can I **remove parts** of the problem in an effort to solve it?	The panel member used the statement **remove parts.** The content of this statement addresses PST ability to augment problems.	augment engineering problems in an effort to solve it.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Combine Elements	P1 T Sec2QA	Can I **combine elements** or techniques to solve the problem?	The panel member used the statement **combine elements.** The content of this statement addresses PST ability to combine elements.	combine elements of engineering problem in an effort to solve it.
Combine Techniques	P1 T Sec2QA	Can I **combine** elements or **techniques** to solve the problem?	The panel member used the statement **combine techniques.** The content of this statement addresses PST ability to combine techniques.	combine techniques of engineering problem in an effort to solve it.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Communicate Engineering Design Solutions	P14 T Sec2QA	Communicate & Reflect – **Share design ideas and solutions** and reflect on the design work, the processes used and decisions made.	The panel member used the statement **share design ideas and solutions.** The content of this statement addresses PST ability to share design ideas and solutions...	share engineering design ideas and solutions to reflect on the design work, the processes used and decisions made.
Create Models	P15 T Sec2QA	**Modeling parts** and 3D printing	The panel member used the statement m**odeling parts.** The content of this statement addresses PST ability to create models.	create engineering models.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Define Engineering by Design	P2 T Sec2QA	Know what '**engineering by designs' means**	The panel member used the statement **engineering by designs' means.** The content of this statement addresses PST ability to define engineering by design.	define the meaning of "engineering by design".
Define Science Content in Engineering Problems	P17 S Sec2QA	help students describe or **define** the **science content** involved **in** the **engineering** problem.	The panel member used the statements **define, science content, in and engineering.** The content of this statement addresses PST ability to define science content in engineering problems.	define science content in engineering problems.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Define Technology	P3 T Sec2QA	At a minimum, they must **know technology is** about modifying the natural world to meet human needs and wants and engineering applies math and science to create technology.	The panel member used the statement **know technology is.** The content of this statement addresses PST ability to define technology.	understand technology is about modifying the natural world to meet human needs and wants and engineering applies math and science to create technology.
Demonstrate Aesthetic Quality	P20 Sec2QA	**Demonstrate** varying levels of **aesthetic quality** in engineering solutions.	The panel member used the statement **demonstrate and aesthetic quality.** The content of this statement addresses PST ability to demonstrate aesthetic quality.	demonstrate aesthetic quality in engineering solutions.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Demonstrate Engineering Design Process	P13 T Sec2QA	Should be able to **perform** the **engineering design process.**	The panel member used the statements **perform and engineering design process...** The content of this statement addresses PST ability to demonstrate the engineering design process.	demonstrate the engineering design process.
Describe Science Content in Engineering Problems	P17 S Sec2QA	help students **describe** or define the **science content** involved **in** the **engineering problem.**	The panel member used the statement **describe, science content, in and engineering problem.** The content of this statement addresses PST ability to describe the science content in an engineering problem.	describe the science content in an engineering problem.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Design Engineering Solutions	P10 S Sec2QA	Teachers must be able to adequately **design engineering solutions** to problems	The panel member used the statement **design engineering solutions.** The content of this statement addresses PST ability to design engineering solutions.	design engineering solutions to a science problem.
Differentiate Between Scientific Inquiry and Engineering Design	P6 T Sec2QA	Understanding of how **engineering** is **differen**t from **science**.	The panel member used the statement **engineering, compare, different from science.** The content of this statement addresses PST ability to differentiate between scientific inquiry and engineering design.	differentiate between scientific inquiry and engineering design.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Differentiate Between Scientific Inquiry and Engineering Design	P17 S Sec2QA	**Compare** and contrast **science** and **engineering** approaches to solving problems.	The panel member used the statement **engineering, compare, different from science.** The content of this statement addresses PST ability to differentiate between scientific inquiry and engineering design.	differentiate between scientific inquiry and engineering design.
Engage in Reflection	P18 T Sec2QA	Engage in **reflection**	The panel member used the statement **reflection.** The content of this statement addresses PST ability to engage in reflection.	engage in reflection.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Explain Design-Based Engineering Practices	P10 S Sec2QA	**Explain** to students how to **design** those solutions	The panel member used the statement **explain and design.** The content of this statement addresses PST ability to explain design-based engineering practices.	explain design-based engineering practices.
Explain Science Behind Engineering	P17 S Sec2QA	**Explain** the **science** content **behind** an **engineering** problem to students--	The panel member used the statement **explain science behind engineering.** The content of this statement addresses PST ability to explain the science content behind an engineering problem.	explain the science content behind an engineering problem.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Generate Strategies	P11 T Sec2QA	Knowledge of various idea-**generating strategies**	The panel member used the statement **idea-generating strategies.** The content of this statement addresses PST ability to understand idea-generating strategies.	understand idea-generating strategies.
Identify Alternative Solutions	P1 T Sec2QA	Is there **another way** to **solve** this problem or use these materials?	The panel member used the statements **another way to solve, new element, and solution.** The content of this statement addresses PST ability to identify alternative solutions.	identify alternative engineering solutions.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Alternative Solutions	P1 T Sec2QA	Can I add a **new element** or twist that might lead to a **solution**?	The panel member used the statements **another way to solve, new element, and solution.** The content of this statement addresses PST ability to identify alternative solutions.	identify alternative engineering solutions.
Identify Alternative Use of Material	P1 T Sec2QA	Is there **another way** to solve this problem or **use** these **materials?**	The panel member used the statement **another way, use and materials.** The content of this statement addresses PST ability to identify alternative use of materials.	identify alternative uses of engineering materials.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Connections Between Science and Engineering	P17 S Sec2QA	Have enough of an understanding of the science to understand the engineering problem, and see **connections** between the **science** and the **engineering.**	The panel member used the statements **connections, science and engineering.** The content of this statement addresses PST ability to identify connections between science and engineering.	identify connections between science and engineering.
Identify Connections Between Science and Engineering	P17 S Sec2QA	Recognize the **science** content **behind** an **engineering** problem.	The panel member used the statements **connections, behind, science and engineering.** The content of this statement addresses PST ability to identify connections between science and engineering.	identify connections between science and engineering.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Design Constraints	P20 T Sec2QA	Define **constraints.**	The panel member used the statement **constraints.** The content of this statement addresses PST ability to identify design constraints.	identify technological/engineering design constraints.
Identify Design Criteria	P20 Sec2QA	Clarify **criteria**.	The panel member used the statement **criteria.** The content of this statement addresses PST ability to identify design criteria.	identify technological/engineering design criteria.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Design Cycle	P12 S Sec2QA	**Know design cycle** and experience it themselves as student learners	The panel member used the statement **know design cycle.** The content of this statement addresses PST ability to identify design cycle.	identify the engineering design cycle.
Identify Grade & Age Appropriate Content	P4 T Sec2QA	Teachers must provide students with **age-appropriate** design challenges.	The panel member used the statement **age-appropriate.** The content of this statement addresses PST ability to identify grade and age appropriate content.	identify grade and age appropriate engineering content.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Grade & Age Appropriate Content	P6 T Sec2QA	Identify what general education aspects of engineering **are appropriate** for K-12 students.	The panel member used the statement **age-appropriate.** The content of this statement addresses PST ability to identify grade and age appropriate content.	identify grade and age appropriate engineering content.
Identify Multiple Solutions	P2 T Sec2QA	Know and practice developing a method that allows them to '**know what to do when we don't know** what to do' when developing problem solving skills	The panel member used the statements **know what to do when we don't know and multiple solutions.** The content of this statement addresses PST ability to identify multiple solutions.	identify multiple solutions to solve an engineering problem.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Multiple Solutions	P5 S Sec2QA	Be able to formulate **multiple solutions** to an engineering problem and use content evidence to support	The panel member used the statements **know what to do when we don't know and multiple solutions.** The content of this statement addresses PST ability to identify multiple solutions.	identify multiple solutions to solve an engineering problem.
Identify Multiple Strategies	P5 S Sec2QA	**Identify multiple strategies** for solving engineering problems.	The panel member used the statement **identify multiple strategies.** The content of this statement addresses PST ability to identify multiple strategies.	identify multiple strategies to solve an engineering problem.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Parameters	P1 T Sec2QA	**Identify** resources, **parameters,** values, etc.	The panel member used the statements **identify and parameters.** The content of this statement addresses PST ability to identify parameters.	identify the parameters to solve an engineering problem.
Identify Resources	P1 T Sec2QA	**Identify resources,** parameters, values, etc.	The panel member used the statement **identify resources.** The content of this statement addresses PST ability to identify resources.	identify resources to solve an engineering problem.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Identify Values	P1 T Sec2QA	**Identify** resources, parameters, **values,** etc.	The panel member used the statements **identify and values.** The content of this statement addresses PST ability to identify values.	identify values to solve an engineering problem.
Implement Design Based Instructional Methods	P10 S Sec2QA	**Construct opportunities** that allow students to **design** those solutions.	The panel member used the statements **construct opportunities, implement design, and methods.** The content of this statement addresses PST ability to implement design based instructional methods.	implement design based engineering instructional methods.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Implement Design Based Instructional Methods	P19 S Sec2QA	**Implement Design**, Technology and Engineering Education Instructional **Methods** & Strategies in technology and engineering and STEM focused curricular applications.	The panel member used the statements **construct opportunities, implement design, and methods.** The content of this statement addresses PST ability to implement design based instructional methods.	implement design based engineering instructional methods.
Implement Design Based Instructional Strategies	P19 S Sec2QA	**Implement Design,** Technology and Engineering Education Instructional Methods & **Strategies i**n technology and engineering and STEM focused curricular applications.	The panel member used the statements **implement design, and strategies.** The content of this statement addresses PST ability to implement design based instructional strategies.	implement design based engineering instructional strategies.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Implement Inquiry-Based Pedagogies	P19 S Sec2QA	**Design** instructional environments that that accommodate **inquiry-based pedagogies,**	The panel member used the statements **design and inquiry-based pedagogies.** The content of this statement addresses PST ability to implement inquiry-based pedagogies.	implement inquiry-based science pedagogies.
Implement STEM Learning Experiences	P19 S Sec2QA	**Implement** and analyze **STEM learning experiences** regarding their focus on State Curriculum Standards for Mathematics, Science, Technology, and Engineering–Grades K-8 (MSDE)	The panel member used the statements **implement and STEM learning experiences.** The content of this statement addresses PST ability to implement STEM learning experiences.	implement STEM learning experiences regarding their focus on state curriculum standards for mathematics, science, technology, and engineering.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Implement State Standards	P19 S Sec2QA	**Implement** and analyze STEM learning experiences regarding their focus on State Curriculum **Standards** for Mathematics, Science, Technology, and Engineering–Grades K-8 (MSDE)	The panel member used the statement **implement standards.** The content of this statement addresses PST ability to implement state standards.	implement state standards regarding their focus on state curriculum standards for mathematics, science, technology, and engineering...
Incorporate Alternative Materials	P1 T Sec2QA	Can I **incorporate** substitutes or use **other materials/**techniques?	The panel member used the statements **incorporate and other materials.** The content of this statement addresses PST ability to incorporate alternative materials.	incorporate alternative materials to solve engineering problems.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Incorporate Alternative Techniques	P1 T Sec2QA	Can I **incorporate** substitutes or use **other** materials/**techniques?**	The panel member used the statements **incorporate, other and techniques.** The content of this statement addresses PST ability to incorporate alternative techniques.	incorporate alternative techniques to solve engineering problems.
Make Informed Decisions	P18 T Sec2QA	How to **make informed decisions,**	The panel member used the statement **make informed decisions.** The content of this statement addresses PST ability to make informed decisions.	make informed decisions to solve engineering problems.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Manage Student Behaviors	P16 S Sec2QA	Pre-service teachers need organization systems to **manage students' behaviors.**	The panel member used the statement **manage students' behaviors.** The content of this statement addresses PST ability to manage student behaviors.	manage student behaviors.
Meet Institutional Goals of Sustainability	P19 S Sec2QA	**meet institutional goals of sustainability**, are welcoming destinations,	The panel member used the statement **meet institutional goals of sustainability.** The content of this statement addresses PST ability to meet institutional goals of sustainability.	meet institutional goals of sustainability.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Model Analytical Skills	P11 T Sec2QA	Knowledge and **ability** to use a variety of **modeling** tools (**analytical**, physical, virtual)	The panel member used the statements **ability, modeling and analytical.** The content of this statement addresses PST ability to model analytical skills.	model a variety of analytical engineering skills.
Model Brainstorming	P16 S Sec2QA	Pre-service teachers must appreciate the value of creativity, collaborative **brainstorming** and be able to **model** that for their students.	The panel member used the statements **brainstorming and model.** The content of this statement addresses PST ability to model brainstorming skills.	model collaborative brainstorming skills.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Model Physical Skills	P11 T Sec2QA	Knowledge and ability to use a variety o**f modeling t**ools (analytical, **physical,** virtual)	The panel member used the statements **ability, modeling and physical.** The content of this statement addresses PST ability to model physical skills.	model a variety of physical engineering skills.
Model Virtual Skills	P11 T Sec2QA	Knowledge and **ability** to use a variety of **modeling t**ools (analytical, physical**, virtual**)	The panel member used the statements **ability, modeling and virtual.** The content of this statement addresses PST ability to model virtual skills.	model a variety of virtual engineering skills.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Practice Design Process	P2 T Sec2QA	Must understand and **practice** the **'design process'**	The panel member used the statements **practice and design process.** The content of this statement addresses PST ability to understand the practice of the design process.	understand the practice of the engineering design process.
Rearrange Elements of a Problem	P1 T Sec2QA	Can I **rearrange** the **elements of the problem** to find the solution?	The panel member used the statement **rearrange the elements of the problem.** The content of this statement addresses PST ability to rearrange the elements of the problem.	rearrange the elements of an engineering problem.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Reflect on Engineering Design Solutions	P14 T Sec2QA	Communicate & Reflect – Share design ideas and solutions and **reflect on the design work,** the processes used and decisions made.	The panel member used the statement **reflect on the design work.** The content of this statement addresses PST ability to reflect on engineering design solutions.	reflect on engineering design solutions.
Sketch and Complete Finished Drawings	P1 T Sec2QA	Additionally, students must be **able** to **sketch and complete finished drawings** (or CAD drawings) of the proposed solution.	The panel member used the statements **sketch and complete finished drawings.** The content of this statement addresses PST ability to sketch and complete finished drawings.	sketch and complete finished technical drawings.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Sketch and Complete Finished Drawings	P15 T Sec2QA	**Sketching** and CAD Design work	The panel member used the statements **sketch and complete finished drawings.** The content of this statement addresses PST ability to sketch and complete finished drawings.	sketch and complete finished technical drawings.
Support Interdisciplinary Collaboration	P19 S Sec2QA	and **support interdisciplinary collaborations.**	The panel member used the statement **support interdisciplinary collaborations.** The content of this statement addresses PST ability to support interdisciplinary collaborations.	support interdisciplinary collaborations.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Take Risk	P16 S Sec2QA	Pre-service teachers must **take risks** and value failures. As much is learned about a solution by design failures as by successes.	The panel member used the statement **take risks.** The content of this statement addresses PST ability to take risks.	take risks when designing a solution.
Test Materials	P15 T Sec2QA	**Material testing** knowledge	The panel member used the statement m**aterial testing.** The content of this statement addresses PST ability to test materials.	test engineering materials.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Standards for Technology Literacy Problem Solving	P3 T Sec2QA	They must **know** about the **common approaches used** in engineering and technology to solve problems (see **Standards for Tech Literacy**).	The panel member used the statements **know about the common approaches used and Standards for Tech literacy.** The content of this statement addresses PST ability to understand the approaches to problem solving found in the Standards for Technology Literacy.	understand the approaches to problem solving found in the Standards for Technology Literacy.
Understand Disciplinary Core Ideas found in NGSS	P16 S Sec2QA	Pre-service teachers must have a strong **understanding** of the **DCIs** in LS, ES and PS. This is usually a deficiency in elementary teachers.	The panel member used the statements **understanding and DCIs** The content of this statement addresses PST ability to understand the Disciplinary Core Ideas found in NGSS.	understand the Disciplinary Core Ideas found in NGSS.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Engineering as a Process	P17 S Sec2QA	**Understand** how the **engineering process** works to design a solution.	The panel member used the statements **understanding and engineering process** The content of this statement addresses PST ability to understand engineering as a process.	understand engineering as a process to design a solution.
Understand Engineering Design	P2 T Sec2QA	Must **understand** and practice the **'design process'**	Panel members used the statements **understanding, engineering, and design process** The content of this statement addresses PST ability to understand the engineering design process.	understand the engineering design process.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Engineering Design	P3 T Sec2QA	They must **know the engineering design process** is used in engineering and technology to solve open-ended real-world problems. Although there are many variations, they should be able to describe the basic steps in the engineering design process.	Panel members used the statements **understanding, engineering, and design process** The content of this statement addresses PST ability to understand the engineering design process.	understand the engineering design process.
Understand Engineering Design	P6 T Sec2QA	**Understanding** that **engineering** is both a technological process as well as a professional discipline.	Panel members used the statements **understanding, engineering, and design process** The content of this statement addresses PST ability to understand the engineering design process.	understand the engineering design process.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Engineering Design	P7 T Sec2QA	**Understand** the steps of the **engineering design** process.	Panel members used the statements **understanding, engineering, and design process** The content of this statement addresses PST ability to understand the engineering design process.	understand the engineering design process.
Understand Engineering Design in Relation to Understanding Science	P5 S Sec2QA	Understand how solving **engineering** problems is a tool for **understanding scientific concepts.** K-12 teachers are not teaching engineering, but using it as an application tool. Designing a solution while emphasizing the main science content requires intentional planning and deliberate focus on the standard objectives.	The panel member used the statements **engineering and understanding scientific concepts.** The content of this statement addresses PST ability to understand engineering design in relation to understanding science.	understand engineering design in relation to understanding science.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Related Engineering Problems	P13 T Sec2QA	Should **understand engineering related problems.**	The panel member used the statement **understand engineering related problems.** The content of this statement addresses PST ability to understand related engineering problems.	understand engineering related problems.
Understand Technical Writing	P13 T Sec2QA	**Understand design/engineer notebooks.**	The panel member used the statement u**nderstand design/engineer notebooks.** The content of this statement addresses PST ability to understand technical writing.	understand technical writing.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Technology Component of STEM	P3 T Sec2QA	They must have a clear understanding and knowledge of the "**T**&E" **components** of **STEM**.	The panel member used the statement **T components of STEM.** The content of this statement addresses PST ability to understand technology components of STEM.	understand technical components of STEM.
Understand the Engineering Component of STEM	P3 T Sec2QA	They must have a clear understanding and knowledge of the "T&**E**" **components** of **STEM.**	The panel member used the statement **E components of STEM.** The content of this statement addresses PST ability to understand engineering components of STEM.	understand engineering components of STEM.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand the Utilization of Materials	P18 T Sec2QA	Optimize, have grit, understand the **role** of **material resources** or lack thereof.	Panel members used the statements **role, material resources, and variety.** The content of this statement addresses PST ability to understand the utilization of materials.	understand the utilization of engineering materials.
Understand the Utilization of Materials	P20 Sec2QA	Exhibit proper use of a **variety of materials.**	Panel members used the statements **role, material resources, and variety.** The content of this statement addresses PST ability to understand the utilization of materials.	understand the utilization of engineering materials.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand the Vocation of Engineering	P6 T Sec2QA	Understanding that **engineering** is both a technological process as well as a **professional** discipline.	Panel members used the statements **engineering, professional, recognize, and engineering fields.** The content of this statement addresses PST ability to understand the vocation of engineering.	understand the vocation of engineering.
Understand the Vocation of Engineering	P6 T Sec2QA	**Recognize** that there are several **engineering fields** that focus on specific issues.	Panel members used the statements **engineering, professional, recognize, and engineering fields.** The content of this statement addresses PST ability to understand the vocation of engineering.	understand the vocation of engineering.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Understand Uses of Models in NGSS	P16 S Sec2QA	Pre-service science teachers need to know the **reason** for **models in the NGSS a**nd how models in engage design differ from models in science.	The panel member used the statement **reason for models in the NGSS.** The content of this statement addresses PST ability to understand the uses of models in NGSS.	understand the use of models in NGSS and how engineering design models differ from models in science.
Use Computer Aided Design	P1 T Sec2QA	Additionally, students must be **able** to sketch and complete finished drawings (or **CAD drawings**) of the proposed solution.	Panel members used the statements **able, complete and CAD.** The content of this statement addresses PST ability to complete computer aided design drawings.	complete computer aided design drawings of proposed solutions.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Use Computer Aided Design	P15 T Sec2QA	Sketching and **CAD** Design work	Panel members used the statements **able, CAD.** The content of this statement addresses PST ability to complete computer aided design drawings.	complete computer aided design drawings of proposed solutions.
Use Engineering Design to Integrate STEM	P7 T Sec2QA	Understand how to **integrate math, science, and other content** areas **using engineering design** as the vehicle.	The panel member used the statements **integrate math, science, and other content areas and using engineering design.** The content of this statement addresses PST ability to utilize engineering design to integrate STEM.	utilize engineering design to integrate STEM.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Use Models to Design Engineering Task	P5 S Sec2QA	Be familiar with **modeling** as a **tool** for **engineering** design and problem-solving.	Panel members used the statements **modeling, tool and engineering.** The content of this statement addresses PST ability to utilize models to design engineering task.	utilize models to design solutions to engineering tasks.
Use Models to Design Engineering Task	P8 S Sec2QA	Teachers must understand how to **use models,** variables, and computational thinking skills to design an engineering task.	Panel members used the statements **modeling, tool and engineering.** The content of this statement addresses PST ability to utilize models to design engineering task.	utilize models to design solutions to engineering tasks.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Utilize Collaboration	P16 S Sec2QA	They need the skills to create a classroom culture that **supports collaboration** and appreciates that designs should be tested to the point of failure.	The panel member used the statement **supports collaboration.** The content of this statement addresses PST ability to utilize collaboration.	create a classroom culture that supports collaboration and appreciates that designs should be tested to the point of failure.
Utilize Graphical Commutations	P18 T Sec2QA	**Use graphical communications**	The panel member used the statement **use graphical communications** The content of this statement addresses PST ability to utilize graphical communications.	utilize graphical communications.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Utilize Modeling	P18 T Sec2QA	**Model**	The panel member used the statement **model** The content of this statement addresses PST ability to utilize modeling.	utilize modeling.
Utilize Real World Examples	P5 S Sec2QA	Research **real world context**s and understand the underlying engineering solutions being used. Then they must **redesign** these scenarios **for** a **classroom** setting.	The panel member used the statements **real world contexts, redesign and for classroom setting.** The content of this statement addresses PST ability to utilize real world examples.	utilize real world engineering examples.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Utilize Systems Thinking	P18 T Sec2QA	**Use systems thinking,**	The panel member used the statements **use systems thinking.** The content of this statement addresses PST ability to utilize systems thinking.	utilize systems thinking.
Utilize Tools and Instruments	P15 T Sec2QA	Modeling parts and **3D printing**	Panel members used the statements 3D printing, safe tool use, and selection of, with testing equipment, general tools and machines**.** The content of this statement addresses PST ability to safely utilize tools, machines and instruments.	safely utilize technological/ engineering tools, machines and instruments.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Utilize Tools and Instruments	P20 Sec2QA	Model safe **tool use**.	Panel members used the statements 3D printing, safe tool use, and selection of, with testing equipment, general tools and machines**.** The content of this statement addresses PST ability to safely utilize tools, machines and instruments.	safely utilize technological/ engineering tools, machines and instruments.
Utilize Tools and Instruments.	P11 T Sec2QA	Understanding of the safety implications of design tasks given to students, and the ability to apply this understanding to judgments about **selection of** activities, **tools, equipment** in the classroom	Panel members used the statements 3D printing, safe tool use, and selection of, with testing equipment, general tools and machines**.** The content of this statement addresses PST ability to safely utilize tools, machines and instruments.	safely utilize technological/ engineering tools, machines and instruments.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Utilize Tools and Instruments.	P14 T Sec2QA	Decide & Build – Balance benefits and tradeoffs in choosing a solution to build; **use tools safely** when making a prototype.	Panel members used the statements 3D printing, safe tool use, and selection of, with testing equipment, general tools and machines**.** The content of this statement addresses PST ability to safely utilize tools, machines and instruments.	safely utilize technological/ engineering tools, machines and instruments.
Utilize Tools and Instruments.	P6 T Sec2QA	They must sacrifice some of their science preparation for engineering courses so that they would have some of the pre-requisite skills, like **working with testing equipment; general tools and machines,** and so forth.	Panel members used the statements 3D printing, safe tool use, and selection of, with testing equipment, general tools and machines**.** The content of this statement addresses PST ability to safely utilize tools, machines and instruments.	safely utilize technological/ engineering tools, machines and instruments.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Utilize Tools and Instruments.	P7 T Sec2QA	Know and **demonstrate** how to safely use **tools** and materials to construct engineering design solutions.	Panel members used the statements 3D printing, safe tool use, and selection of, with testing equipment, general tools and machines**.** The content of this statement addresses PST ability to safely utilize tools, machines and instruments.	safely utilize technological/ engineering tools, machines and instruments.
Utilize Tools and Instruments.	P13 T Sec2QA	**Utilization of engineering tools,** instruments, etc...	Panel members used the statements 3D printing, safe tool use, and selection of, with testing equipment, general tools and machines**.** The content of this statement addresses PST ability to safely utilize tools, machines and instruments.	safely utilize technological/ engineering tools, machines and instruments.

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Competency	Panel #	Evidence	Rationale	Round 2 Statement
Value Failure	P16 S Sec2QA	Pre-service teachers must take risks and **value failures.** As much is learned about a solution by design failures as by successes.	The panel member used the statements **value failures.** The content of this statement addresses PST ability to value failures.	value failures.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Applying Engineering Problems and Processes to Specific Science Content	P17 S Sec2QB	Expose students to **engineering problems and processes applied to** specific **science** content.	The panel member used the statements **engineering problems and processes applied to and science.** The content of these statements addresses how teacher educators should engage their students in applying engineering problems and processes to specific science content.	applying engineering problems and processes to specific science content.
Authentic Problem Solving Activities	P2 T Sec2QB	Develop their **problem solving** skills by introducing **'real world' problems**	Panel members used the statements **problem solving and real world problems, design process, solve open ended real world problems.** The content of these statements addresses how teacher educators should engage their students in authentic problem solving activities.	authentic engineering problem solving activities.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Authentic Problem Solving Activities	P3 T Sec2QB	They must know the engineering **design process** is used in engineering and technology to **solve open-ended real-world problems.**	Panel members used the statements **problem solving and real world problems, design process, solve open ended real world problems.** The content of these statements addresses how teacher educators should engage their students in authentic problem solving activities.	authentic engineering problem solving activities.
Authentic Problem Solving Activities	P13 T Sec2QB	Connect the design problems and process to the students **"real world" life.**	Panel members used the statements **problem solving and real world problems, design process, solve open ended real world problems.** The content of these statements addresses how teacher educators should engage their students in authentic problem solving activities.	authentic engineering problem solving activities.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Brainstorming Ideas for Solutions	P2 T Sec2QB	Working in groups to '**brain-storm' ideas** for **solutions**	The panel member used the statement **'brain-storm' ideas and solutions** The content of these statements addresses how teacher educators should engage their students in brainstorming ideas for solutions.	brainstorming ideas for engineering solutions.
Building Arguments from Evidence	P16 S Sec2QB	Model **Engaging in argument** from **evidence.**	The panel member used the statement **Engaging in argument from evidence.** The content of these statements addresses how teacher educators should engage their students in building arguments from evidence.	building arguments from evidence.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Building Technical Devices	P2 T Sec2QB	Actually **develop models** to their solutions	The panel member used the statement **develop models.** The content of these statements addresses how teacher educators should engage their students in building technical devices.	building technical devices.
Capstone Projects	P15 T Sec2QB	**Capstone projects**	The panel member used the statement **Capstone projects.** The content of these statements addresses how teacher educators should engage their students in Capstone projects.	Capstone projects.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Collaborative Brainstorming Activities	P16 S Sec2QB	**Collaborative brainstorming.**	The panel member used the statement c**ollaborative brainstorming.** The content of these statements addresses how teacher educators should engage their students in collaborative brainstorming activities.	collaborative brainstorming activities.
Computer Aided Design	P1 T Sec2QB	Questioning, envisioning the solution (sketching, orthographic projection, perspective drawing, **CAD** drawing, etc.)	The panel member used the statement **CAD.** The content of these statements addresses how teacher educators should engage their students in Computer Aided Design.	Computer Aided Design.
Computer Aided Design	P3 T Sec2QB	They should be able to **use 2D & 3D CAD Software** and other types of modeling software.	The panel member used the statement **CAD.** The content of these statements addresses how teacher educators should engage their students in Computer Aided Design.	Computer Aided Design.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Concurrent Engineering Activities	P15 T Sec2QB	**Concurrent engineering**	The panel member used the statement **concurrent engineering.** The content of these statements addresses how teacher educators should engage their students in concurrent engineering activities.	concurrent engineering activities.
Coping With K-12 Student Failure	P18 T Sec2QB	**Help students cope** with **failure.**	The panel member used the statement h**elp students cope with failure.** The content of these statements addresses how teacher educators should engage their students in coping with K-12 student failure.	coping with K-12 student failure.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Courses with Breadth and Depth in Science Concepts	P17 S Sec2QB	Ensure a solid foundation in appropriate **science content--depth and breadth.** Enough courses, appropriate focus.	The panel member used the statement **science content--depth and breadth.** The content of these statements addresses how teacher educators should engage their students in courses with breadth and depth in science concepts.	courses with breadth and depth in science concepts.
Dealing with K-12 Student Resistance When There is Not a Clear Path	P18 T Sec2QB	**Deal with student resistance** when there is **not a clear path -**	The panel member used the statement d**eal with student resistance when there is not a clear path.** The content of these statements addresses how teacher educators should engage their students in dealing with K-12 student resistance when there is not a clear path.	dealing with K-12 student resistance when there is not a clear path.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Demonstrating the Utilization of Materials	P19 S Sec2QB	**Demonstrations** of how **various material**s and/or activities can be **utilized** in the curriculum.	The panel member used the statements **demonstrations, various materials and utilized.** The content of these statements addresses how teacher educators should engage their students in demonstrating the utilization of materials.	demonstrating the utilization of science materials
Demonstrations	P11 T Sec2QB	**Demonstrations**	The panel member used the statement **demonstrations**. The content of these statements addresses how teacher educators should engage their students in demonstrations.	demonstrations.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Demonstrations of Utilizing Engineering Design	P20 Sec2QB	**Demonstrate** a structured process for **designing engineering solutions.**	The panel member used the statement d**emonstrate a structured process for designing engineering solutions.**.. The content of these statements addresses how teacher educators should engage their students in demonstrations of utilizing engineering design.	demonstrating a structured process for designing engineering solutions.
Describing Steps of Engineering Design Process	P3 T Sec2QB	Although there are many variations, they should be able to **describe** the basic steps in the **engineering design process**	The panel member used the statements **describe and engineering design process.** The content of these statements addresses how teacher educators should engage their students in describing the steps of engineering design process.	describing the basic steps of engineering design process.
Design Teams	P15 T Sec2QB	**Design teams**	The panel member used the statement **design teams.** The content of these statements addresses how teacher educators should engage their students in design teams.	design teams.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Designing Lessons	P6 T Sec2QB	**Lesson planning**	The panel member used the statement **lesson planning.** The content of these statements addresses how teacher educators should engage their students in lesson planning.	lesson planning.
Developing Knowledge of Technical Skills	P6 T Sec2QB	General **technical skills and knowledge.**	The panel member used the statement **technical skills and knowledge.** The content of these statements addresses how teacher educators should engage their students in developing knowledge of technical skills.	developing knowledge of general technical skills.
Developing Solutions	P2 T Sec2QB	**Develop** possible **solutions**	The panel member used the statement **develop and solutions.** The content of these statements addresses how teacher educators should engage their students in developing solutions.	developing possible engineering solutions.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Differentiating Invention vs. Innovation	P2 T Sec2QB	Define the **difference** between **invention and innovation**	The panel member used the statements **difference and invention and innovation.** The content of these statements addresses how teacher educators should engage their students in differentiating invention and innovation.	differentiating invention and innovation.
Discussing Concepts of the NGSS	P19 S Sec2QB	Discussion- engaging students in **discussions surrounding** the **concepts of NGSS** and the integration of subjects as well as how the engineering design practices should be embedded within the curriculum	The panel member used the statement **discussions surrounding the concepts of NGSS** The content of these statements addresses how teacher educators should engage their students in discussing the concepts of NGSS.	discussing the concepts of the NGSS and the integration of subjects as well as how the engineering design practices should be embedded within the curriculum.
Documenting Their Design Work	P13 T Sec2QB	Require students to **document their design work** with notebooks.	The panel member used the statement **document their design work.** The content of these statements addresses how teacher educators should engage their students in documenting design work.	documenting engineering design work.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Engaging Students Activities That Require Debugging	P8 S Sec2QB	Teacher educators should **give** pre-service teachers engineer **assignments** that **require debugging.**	The panel member used the statement **give and assignments that require debugging.** The content of these statements addresses how teacher educators should engage their students in activities requiring debugging.	engineering activities that requiring debugging.
Engineering Design Process	P16 S Sec2QB	**Participate in design building, testing and data collection.**	The panel member used the statement p**articipate in design building, testing and data collection.** The content of these statements addresses how teacher educators should engage their students in the engineering design process.	the engineering design process.
Engineering Problem Solving Methodology	P5 S Sec2QB	Instruction in the **methodology of problem-solving** and how it is applied to engineering practices.	The panel member used the statement **methodology of problem-solving.** The content of these statements addresses how teacher educators should engage their students in engineering problem solving methodology.	instruction in the methodology of problem-solving and how it is applied to engineering practices.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Envisioning Solutions	P1 T Sec2QB	Questioning, **envisioning** the **solution** (sketching, orthographic projection, perspective drawing, CAD drawing, etc.)	The panel member used the statement **envisioning the solution.** The content of these statements addresses how teacher educators should engage their students in envisioning solutions.	envisioning solutions through the use of sketching, orthographic projection, perspective drawing, CAD drawing, etc.
Evaluating Strengths and Weaknesses of Exemplar Science and Engineering Lessons	P17 S Sec2QB	Study excellent, good, and poor lessons that model science content and engineering--identify and **evaluate strengths and weaknesses of the lessons.**	The panel member used the statement **evaluate strengths and weaknesses of the lessons.** The content of these statements addresses how teacher educators should engage their students in evaluating the strengths and weaknesses of an exemplar science and engineering lesson.	evaluating the strengths and weaknesses of an exemplar science and engineering lesson.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Experiencing Cooperative Learning Strategies	P12 S Sec2QB	Should **learn cooperative learning strategies,** group discourse tools and inquiry (data collection and analysis) as well as argumentation skills	The panel member used the statement **learn cooperative learning strategies,** The content of these statements addresses how teacher educators should engage their students in experiencing cooperative learning strategies.	experiencing cooperative learning strategies.
Experiencing Hands-On Engineering Design Activities in Their Content Area	P12 S Sec2QB	and **experience hands on** content based **engineering design** challenge **activities** in their **content area** (bio, Chem, physics).	The panel member used the statements **experience hands on, engineering design, activities and content area.** The content of these statements addresses how teacher educators should engage their students in experiencing hands-on engineering design activities in their own content area.	experiencing hands-on engineering design activities in their own content area.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Experiencing Problems that Require Engineering-Type Solutions	P10 S Sec2QB	Pre-service teachers should **experience** situations where they are exposed to **problems** that **require** an **engineering-**type **solution** (so that they can experience the process).	The panel member used the statements **experience, problems, require, and engineering-type solution.** The content of these statements addresses how teacher educators should engage their students in experience problems that require an engineering-type solution.	experiencing problems that require an engineering-type solution.
Exposure to Multiple Design Methods	P13 T Sec2QB	**Expose** future teachers to **many different design methods.**	The panel member used the statements **expose and many different design methods.** The content of these statements addresses how teacher educators should engage their students in exposure to multiple design methods.	exposure to multiple engineering design methods.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Facilitated Lessons	P4 T Sec2QB	Teachers must employ **coaching and facilitation methodologies.**	Panel members used the statements **coaching and facilitation methodologies and guided practice.** The content of these statements addresses how teacher educators should engage their students in facilitated lessons.	facilitated lessons.
Facilitated Lessons	P11 T Sec2QB	**Guided practice**	Panel members used the statements **coaching and facilitation methodologies and guided practice.** The content of these statements addresses how teacher educators should engage their students in facilitated lessons.	facilitated lessons.
Group Facilitation	P4 T Sec2QB	Teachers must **use group facilitation** techniques.	The panel member used the statement **use group facilitation.** The content of these statements addresses how teacher educators should engage their students in group facilitation.	group facilitation.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Hands-on Design Activities	P6 T Sec2QB	**Hands-on design activities.**	The panel member used the statement **hands-on design activities.** The content of these statements addresses how teacher educators should engage their students in hands-on design activities.	hands-on engineering design activities.
Hands-on Problem Solving Activities	P6 T Sec2QB	**Hands-on problem solving activities.**	The panel member used the statement **hands-on problem solving activities.** The content of these statements addresses how teacher educators should engage their students in hands-on problem solving activities.	hands-on engineering problem solving activities.
Identifying Areas of a Lesson that can be Enriched with Engineering Design	P7 T Sec2QB	**Identify** areas where the **lesson** could be **enriched** with greater STEM connections or authentic **engineering design.**	The panel member used the statements **identify, lesson, enriched, engineering design.** The content of these statements addresses how teacher educators should engage their students in identifying areas of a lesson that can be enriched with engineering design.	identifying areas of a lesson that can be enriched with engineering design.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Identifying Areas of a Lesson that can be Enriched with STEM Connections	P7 T Sec2QB	**Identify** areas where the **lesson** could be **enriched** with greater **STEM connections** or authentic engineering design.	The panel member used the statements **identify, lesson, enriched,** and **STEM connections.** The content of these statements addresses how teacher educators should engage their students in identifying areas of a lesson that can be enriched with STEM connections.	identifying areas of a lesson that can be enriched with STEM connections
Identifying Problems Experienced by K-12 Students	P8 S Sec2QB	Teachers need to be able to **see** where **problems** may arise in order to help their **students.**	The panel member used the statements **see, problems and students.** The content of these statements addresses how teacher educators should engage their students in identifying problems experienced by K-12 students.	identifying problems experienced by K-12 science students.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Identifying Steps of Engineering Design Process During Reflection	P7 T Sec2QB	Intentionally **identify steps** of the **engineering design** process that students explain they went through when **summarizing** their experience.	The panel member used the statements **identifying, engineering design and summarizing.** The content of these statements addresses how teacher educators should engage their students in identifying steps of the engineering design process during reflection.	identifying steps of the engineering design process during reflection.
Identifying Strengths and Weaknesses of Exemplar Science and Engineering Lessons	P17 S Sec2QB	Study excellent, good, and poor lessons that model science content and engineering--**identify** and evaluate **strengths and weaknesses** of the **lessons.**	The panel member used the statements **identifying and strengths and weaknesses of the lessons.** The content of these statements addresses how teacher educators should engage their students in identifying the strengths and weaknesses of exemplar science and engineering lessons.	identifying the strengths and weaknesses of exemplar science and engineering lessons.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Identifying the Vocation of Engineering	P17 S Sec2QB	Expose students to engineering practices, w**hat does an engineer** really **do** and how do they do it? Help understand the engineering process.	Panel members used the statement **what does an engineer do.** The content of these statements addresses how teacher educators should engage their students in exploring the vocation of engineering.	identifying the vocation of engineering.
Identifying the Vocation of Engineering	P12 S Sec2QB	Again, **know what engineers do**	Panel members used the statement **what does an engineer do.** The content of these statements addresses how teacher educators should engage their students in exploring the vocation of engineering.	identifying the vocation of engineering.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Incorporating Design Activities into Case Study Exploration	P9 S Sec2QB	**Design Act Learning** Teaching Strategies **incorporated** into **Case Study exploration** and resolution.	The panel member used the statements **design act learning, incorporated and case study exploration.** The content of these statements addresses how teacher educators should engage their students in incorporating design activities into case study exploration.	incorporating design activities into case study exploration and resolution.
Iterative Design Activities	P14 T Sec2QB	**Iterative Design**	The panel member used the statement **iterative design.** The content of these statements addresses how teacher educators should engage their students in iterative design activities.	iterative engineering design activities.
Modeled Visualization Techniques	P20 Sec2QB	**Model visualization techniques.**	The panel member used the statement m**odel visualization techniques.** The content of these statements addresses how teacher educators should engage their students in model visualization techniques.	modeling visualization techniques.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Modeling Design Based Engineering Practices	P5 S Sec2QB	The immersion of pre-service teachers in **modeling practices designed to solve engineering problems.**	The panel member used the statements **modeling and practices designed to solve engineering problems.** The content of these statements addresses how teacher educators should engage their students in modeling design based engineering practices.	modeling design based engineering practices.
Modeling Safe Tool Use	P7 T Sec2QB	**Model safer use** of engineering **tools,** machines, and processes to design engineering design solutions.	The panel member used the statements **modeling safe use, and tools.** The content of these statements addresses how teacher educators should engage their students in modeling safe tool use.	modeling safe technology/engineering tool use.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Open-Ended, Multiple Solution Problems	P4 T Sec2QB	Teachers must **encourage** a variety of **solution possibilities**	The panel member used the statements **encourage, variety, and solution possibilities.** The content of these statements addresses how teacher educators should engage their students in open-ended, multiple solution problems.	open-ended, multiple solution problems.
Peer Evaluations	P5 S Sec2QB	Students work in small groups and engage in regular **peer review** for the improvement of engineering designs.	The panel member used the statement **peer review.** The content of these statements addresses how teacher educators should engage their students in peer evaluations.	peer evaluations for the improvement of engineering designs.
Practicing Design Problems	P13 T Sec2QB	**Practice** with **design problems.**	The panel member used the statements **practice and design problems.** The content of these statements addresses how teacher educators should engage their students in practicing design problems.	practicing engineering design problems.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Predictive Modeling	P14 T Sec2QB	**Modeling** (representational and **predictive)**	The panel member used the statements **modeling and predictive.** The content of these statements addresses how teacher educators should engage their students in predictive modeling.	predictive modeling.
Proposing Design Solutions That Consider Human and Environmental Factors	P14 T Sec2QB	**Consider Human Factors** (e.g., health, safety, and ergonomics) and Environmental Impacts when **Proposing Design Solutions.**	The panel member used the statements c**onsider human factors and proposing design solutions.** The content of these statements addresses how teacher educators should engage their students in proposing design solutions that consider human and environmental factors.	proposing design solutions that consider human and environmental factors.
Reflecting on Key Scientific Concepts Identified in NGSS	P5 S Sec2QB	Students are asked to **reflect** on how their design solutions enhance their knowledge of **key scientific concept**s identified by the **NGSS standards**.	The panel member used the statements **reflect, key scientific concepts and NGSS standards.** The content of these statements addresses how teacher educators should engage their students in reflecting on key scientific concepts identified in NGSS.	reflecting on key scientific concepts identified and conceptual shifts in NGSS.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Representation Modeling	P14 T Sec2QB	**Modeling** (**representational** and predictive)	The panel member used the statements **modeling and representational.** The content of these statements addresses how teacher educators should engage their students in representation modeling.	representation modeling
Risk Taking Classroom Culture Structures	P16 S Sec2QB	**Classroom** culture that supports **risk taking**.	The panel member used the statements **classroom and risk taking** The content of these statements addresses how teacher educators should engage their students in risk taking classroom culture structures.	risk taking classroom culture structures.
Age & Grade Appropriate Design Activities	P11 T Sec2QB	**Engage** students in **sample design activities** that would be **appropriate** for the **target grade levels** they will teach	The panel member used the statements **Engage, design activities, appropriate and target grade levels** The content of these statements addresses how teacher educators should engage their students in age and grade appropriate design activities.	age and grade appropriate engineering design activities.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Selecting Appropriate Resources	P14 T Sec2QB	**Select** and Using **Appropriate Resources**	The panel member used the statements **select and appropriate resources.** The content of these statements addresses how teacher educators should engage their students in selecting appropriate resources.	selecting appropriate technological/engineering resources.
Sketching	P1 T Sec2QB	Questioning, envisioning the solution (**sketching,** orthographic projection, perspective drawing, CAD drawing, etc.)	The panel member used the statements **sketching.** The content of these statements addresses how teacher educators should engage their students in sketching.	technical sketching.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Systems Thinking	P14 T Sec2QB	**Systems Thinking**	The panel member used the statement **systems thinking.** The content of these statements addresses how teacher educators should engage their students in systems thinking.	systems thinking.
Technical Drawings	P1 T Sec2QB	Questioning, envisioning the solution (sketching, **orthographic projection, perspective drawing,** CAD **drawing,** etc.)	Panel members used the statements **orthographic projection, perspective drawing, CAD drawing, and practice in drawing and sketching and engineering designs.** The content of these statements addresses how teacher educators should engage their students in technical drawings.	technical drawings.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Technical Drawings	P5 S Sec2QB	Students are given **practice in drawing and sketching** observed phenomena and **engineering designs.**	Panel members used the statements **orthographic projection, perspective drawing, CAD drawing, and practice in drawing and sketching and engineering designs.** The content of these statements addresses how teacher educators should engage their students in technical drawings.	technical drawings.
Technical Writing	P20 Sec2QB	Produce **design documentation** that can be **replicated**.	The panel member used the statements **design documentation and replicated.** The content of these statements addresses how teacher educators should engage their students in technical writing.	technical writing.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Testing of Engineering Design Solutions	P5 S Sec2QB	Given an engineering problem, students are asked to formulate multiple engineering solutions. Then they must use scientific evidence and prior observation to determine which proposed solution might be most successful. Finally, students **implement the solution** to **verify** the success of the **engineering design**.	The panel member used the statements **implement the solution, verify and engineering design.** The content of these statements addresses how teacher educators should engage their students in testing of engineering design solutions.	testing of engineering design solutions.
Tool Use	P3 T Sec2QB	They should be given hands-on experience **using** real-world **tools** and materials in the solving of an actual engineering type problem.	The panel member used the statements **using and tools.** The content of these statements addresses how teacher educators should engage their students in tool use.	technology/engineering tool use.
Trial and Error Activities	P5 S Sec2QB	Students engage in **trial and error** of design production and implementation.	The panel member used the statements **trial and error.** The content of these statements addresses how teacher educators should engage their students in trial and error activities.	trial and error activities of design production and implementation.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Appropriate Resources	P14 T Sec2QB	Select and **Using Appropriate Resources**	The panel member used the statement **using appropriate resources.** The content of these statements addresses how teacher educators should engage their students in utilizing appropriate resources.	utilizing appropriate technical/engineering resources.
Using Data Collection	P2 T Sec2QB	**Collect data** based on their **solutions** to the problem	The panel member used the statements **collect data and solutions.** The content of these statements addresses how teacher educators should engage their students in utilizing data collection.	collect data based on their solutions to the problem.
Using Engineering Design to Integrate Multiple Content Areas into Science	P7 T Sec2QB	Demonstrate how to intentionally **integrate multiple content areas** into **science** instruction using **engineering design**.	The panel member used the statements **integrate multiple content areas, science and engineering design.** The content of these statements addresses how teacher educators should engage their students in utilizing engineering design to integrate multiple content areas into science.	utilizing engineering design to integrate multiple content areas into science.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Using Scientific Evidence to Evaluate Solutions to Engineering Problems.	P5 S Sec2QB	Given an **engineering problem,** students are asked to formulate multiple engineering solutions. Then they must **use scientific evidence** and prior observation to determine which proposed solution might be most successful. Finally, students implement the solution to verify the success of the engineering design.	The panel member used the statements **engineering problem and use scientific evidence.** The content of these statements addresses how teacher educators should engage their students in utilizing scientific evidence to evaluate solutions to engineering problems.	utilizing scientific evidence to evaluate solutions to engineering problems.
Utilizing Cooperative Learning Activities	P19 S Sec2QB	**Cooperative learning**/group work- to ensure that there are a diverse set of skills present and so students can see how teams are vital to the success of an engineering project.	The panel member used the statement **cooperative learning.** The content of these statements addresses how teacher educators should engage their students in utilizing cooperative learning activities.	utilizing cooperative learning activities so students can see how teams are vital to the success of an engineering project.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing Media Presentations	P19 S Sec2QB	**Media presentations**- both teacher educators and pre-service teachers alike should be utilizing technology to show examples of collaborative work skills in engineering design as well as to present their findings.	The panel member used the statement **media presentations.** The content of these statements addresses how teacher educators should engage their students in utilizing media presentations.	utilizing media presentations to show examples of collaborative work skills in engineering design as well as to present their findings.
Utilizing Mini Lectures on Engineering Design Concepts	P19 S Sec2QB	**Mini-lectures** to provide key information to teachers on **engineering design concepts** as well as additional subject matter that may be new to them.	The panel member used the statements **mini lectures and engineering design concepts.** The content of these statements addresses how teacher educators should engage their students in utilizing mini lectures on engineering design concepts.	utilizing mini lectures on engineering design concepts.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing Concept Mapping	P6 T Sec2QB	**Conceptual Mapping.**	The panel member used the statement **conceptual mapping.** The content of these statements addresses how teacher educators should engage their students in utilizing concept mapping.	utilizing concept mapping.
Utilizing Formative Assessments	P18 T Sec2QB	As most engineering design problems are ill-defined, **use formative assessment** methods	The panel member used the statement **use formative assessment.** The content of these statements addresses how teacher educators should engage their students in utilizing formative assessment.	utilizing formative assessment for engineering design.

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing Peer Sharing	P19 S Sec2QB	**Peer sharing-** pre-service teachers need to be able to teach these concepts to others as well as present their findings in an effective manner.	The panel member used the statement **peer sharing.** The content of these statements addresses how teacher educators should engage their students in utilizing peer sharing.	utilizing peer sharing.
Writing Lessons for Engineering Applications of Science Content	P17 S Sec2QB	**Write lessons for an engineering application of science content.**	The panel member used the statement w**rite lessons for an engineering application of science content.** The content of these statements addresses how teacher educators should engage their students in writing lessons for engineering applications of science content.	writing lessons for engineering applications of science content.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Analyzing the Appropriateness of a Design Activity	P11 T Sec3QS	**Analyze sample design activities** to try to 'unpack' science content. Provide critiques of the **appropriateness**/effectiveness of the activity.	The panel member used the statements a**nalyze sample design activities and appropriateness.** The content of these statements addresses how teacher educators should engage their students in analyzing the appropriateness of a design activity.	analyzing the appropriateness of an engineering design activity.
Analyzing the Effectiveness of a Design Activity	P11 T Sec3QS	**Analyze sample design activities** to try to 'unpack' science content. Provide critiques of the appropriateness/**effectiveness** of the activity.	The panel member used the statements a**nalyze sample design activities and effectiveness.** The content of these statements addresses how teacher educators should engage their students in analyzing the effectiveness of a design activity.	analyzing the effectiveness of an engineering design activity.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Applying Engineering Practices to a Problem Clearly Linked to Science Content	P17 S Sec3QS	Lessons or activities that explicitly ask students to **apply engineering practices to a problem clearly linked to science content.**	The panel member used the statements **apply engineering practices to a problem clearly linked to science content.** The content of these statements addresses how teacher educators should engage their students in applying engineering practices to a problem clearly linked to science content.	applying engineering practices to a problem clearly linked to science content.
Approaching Engineering as a Way of Doing	P18 T Sec3QS	So, engineering is not just a pedagogical method, **but a way of** thinking and **doing**. It is far too easy for a teacher to say they are doing engineering when in reality, they are not.	The panel member used the statements **but a way and doing content.** The content of these statements addresses how teacher educators should engage their students in approaching engineering as a way of doing.	approaching engineering as a way of doing.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Approaching Engineering as a Way of Thinking	P18 T Sec3QS	So, engineering is not just a pedagogical method, **but a way of thinking** and doing. It is far too easy for a teacher to say they are doing engineering when in reality, they are not.	The panel member used the statement **but a way of thinking** The content of these statements addresses how teacher educators should engage their students in approaching engineering as a way of thinking.	approaching engineering as a way of thinking.
Authentic Problem Solving Activities	P5 S Sec3QS	I view the addition of engineering practices to the standards in much the same way. We must engage our pre-service teachers in the process of identifying the key science content, exposing them to scientific phenomena, determining the questions and (now) engineering problems that **put** this content **into real world contexts,** and design investigative and/or engineering solutions that will increase our understanding of the content.	Panel Members used the statements **into real world contexts, teacher, engage and practical problems.** The content of these statements addresses how teacher educators should engage their students in authentic problem solving activities.	authentic science problem solving activities.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Authentic Problem Solving Activities	P10 S Sec3QS	There is a lot of overlap between scientific practices and engineering practices. The latter is best suited for practical problems, which can be used to make the science content relevant. Consequently, pre-service **teachers** should **engage** in experiences where **practical problems** are used as the context for **exploring scientific content.**	Panel Members used the statements **into real world contexts, teacher, engage and practical problems.** The content of these statements addresses how teacher educators should engage their students in authentic problem solving activities.	authentic science problem solving activities.
Combining Different Benchmarks in the NGSS to Identify how the Design Process Can be Used	P13 T Sec3QS	Revisit the NGSS and investigate ways the **design process** can be used to teach specific content by **combining different** standards and **benchmarks.**	Panel Members used the statements **combining different standards and benchmarks design process.** The content of these statements addresses how teacher educators should engage their students in combining different benchmarks in the NGSS to identify how the design process can be used.	the NGSS to identify how the design process can be used to teach specific content by combining different standards and benchmarks.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Content Knowledge Identified in the NGSS	P5 S Sec3QS	Instructional strategies include both science-specific pedagogical approaches to engage the process of learning (e.g. the use of inquiry and modeling curriculum), and the continuous assessment of whether these approaches are progressing **content knowledge identified in the NGSS** standards. We model these practices for our pre-service teachers, who will then do them with their future students.	The panel members used the statement **content knowledge identified in the NGSS.** The content of these statements addresses how teacher educators should engage their students in combining different benchmarks in content knowledge identified in the NGSS.	content knowledge identified in the NGSS.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Contrasting Processes Used by Scientists with those Used by Professionals in Other Disciplines.	P20 Sec3QS	**Contrast processes used by scientists with those used by professionals in other disciplines.**	The panel members used the statement c**ontrast processes used by scientists with those used by professionals in other disciplines.** The content of these statements addresses how teacher educators should engage their students in contrasting processes used by scientists with those used by professionals in other disciplines.	contrasting processes used by scientists with those used by professionals in other disciplines.
Cooperative Learning	P19 S Sec3QS	**Cooperative learning,**	The panel members used the statement c**ooperative learning.** The content of these statements addresses how teacher educators should engage their students in cooperative learning.	cooperative learning.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Creating Tools and Instrumentation for Collecting Scientific Data	P20 Sec3QS	**Create tools and instrumentation for collecting scientific data.**	The panel members used the statement **create tools and instrumentation for collecting scientific data.** The content of these statements addresses how teacher educators should engage their students in creating tools and instrumentation for collecting scientific data.	creating tools and instrumentation for collecting scientific data.
Critiquing Engineering Lessons to Identify Science Content	P17 S Sec3QS	Ask students to **critique engineering lessons to look for the science,** and science lessons to look for the engineering.	The panel members used the statement **critique engineering lessons to look for the science.** The content of these statements addresses how teacher educators should engage their students in critiquing engineering lessons to identify science content.	critiquing engineering lessons to identify science content.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Critiquing Science Lessons to Identify Engineering Content	P17 S Sec3QS	Ask students to **critique** engineering lessons to look for the science, and **science lessons to look for the engineering.**	The panel members used the statement **critique and science lessons to look for the engineering.** The content of these statements addresses how teacher educators should engage their students in critiquing science lessons to identify engineering content.	critiquing science lessons to identify engineering content.
Experiencing Exemplary Design Activities	P11 T Sec3QS	**Carry out design activities** that are considered exemplary: Let pre-service teachers **experience** a well-**design activity** and then discuss it afterward	The panel members used the statement **carry out design activities and experience a well-design activity.** The content of these statements addresses how teacher educators should engage their students in delivering experiencing design activities.	experiencing exemplary engineering design activities.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Designing Engineering Solutions	P5 S Sec3QS	I view the addition of engineering practices to the standards in much the same way. We must engage our pre-service teachers in the process of identifying the key science content, exposing them to scientific phenomena, determining the questions and (now) engineering problems that put this content into real world contexts, and **design** investigative and/or **engineering solutions** that will increase our understanding of the content.	The panel members used the statement d**esigning engineering solutions.** The content of these statements addresses how teacher educators should engage their students in designing engineering solutions.	designing engineering solutions.
Designing Investigative Solutions	P5 S Sec3QS	I view the addition of engineering practices to the standards in much the same way. We must engage our pre-service teachers in the process of identifying the key science content, exposing them to scientific phenomena, determining the questions and (now) engineering problems that put this content into real world contexts, and **design investigative** and/or	The panel members used the statement d**esigning investigative solutions.** The content of these statements addresses how teacher educators should engage their students in designing investigative solutions.	designing investigative science solutions.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
		engineering **solutions** that will increase our understanding of the content.		
Designing Lesson Plans, Teaching and Reflecting on Lessons	P12 S Sec3QS	**Have students design lesson plans, teach and reflect on these lessons**	The panel members used the statement h**ave students design lesson plans, teach and reflect on these lessons.** The content of these statements addresses how teacher educators should engage their students in designing lesson plans, teaching and then reflecting on these lessons.	designing science lesson plans, teaching and then reflecting on these lessons.
Determining Engineering Problems	P5 S Sec3QS	I view the addition of engineering practices to the standards in much the same way. We must engage our pre-service teachers in the process of identifying the key science content, exposing them to scientific phenomena, **determining** the questions and (now) **engineering problems** that put this content into real world contexts, and design investigative and/or engineering solutions that will increase our understanding of	The panel members used the statements **determining and engineering problems.** The content of these statements addresses how teacher educators should engage their students in determining engineering problems.	determining engineering problems.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
		the content.		
Determining Science Questions	P5 S Sec3QS	I view the addition of engineering practices to the standards in much the same way. We must engage our pre-service teachers in the process of identifying the key science content, exposing them to scientific phenomena, **determining the questions** and (now) engineering problems that put this content into real world contexts, and design investigative and/or engineering solutions that will increase our understanding of the content.	The panel members used the statements **determining and science questions.** The content of these statements addresses how teacher educators should engage their students in determining science questions.	determining science questions.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Developing Age & Grade Appropriate Engineering Design Challenges	P4 T Sec3QS	Teacher educators should provide opportunities for teacher education candidates to learn how to *develop* and facilitate the implementation of **age-appropriate engineering design challenges.**	The panel members used the statement **age-appropriate engineering design challenges.** The content of these statements addresses how teacher educators should engage their students in developing age and grade appropriate engineering design challenges.	developing age and grade appropriate engineering design challenges.
Developing Situational Awareness	P1 T Sec3QS	**Notice** what **appears out of place** (e.g., Observe a malfunctioning system in operation to determine what is not working correctly.)	The panel members used the statement n**otice what appears out of place.** The content of these statements addresses how teacher educators should engage their students in developing situational awareness.	developing situational awareness of malfunctioning systems in operation to determine what is not working correctly.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Developing Standards Based Activities	P3 T Sec3QS	I would **develop standards-based activities** and experiences that require student to apply both the engineering design process and scientific method in the solving an engineering/technology problem	The panel members used the statement **develop standards-based activities.** The content of these statements addresses how teacher educators should engage their students in developing standards-based activities.	developing standards-based engineering activities.
Developing Standards Based Experiences	P3 T Sec3QS	I would **develop standards-base**d activities and **experiences** that require student to apply both the engineering design process and scientific method in the solving an engineering/technology problem	The panel members used the statement **develop standards-based activities and experiences.** The content of these statements addresses how teacher educators should engage their students in developing standards-based activities.	developing standards-based engineering experiences.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Discussing STEM Concepts	P3 T Sec3QS	In this activity or experience, I would also require them to identify and **discuss** all important **STEM concept**s associated with the activity or experience.	The panel members used the statements **discuss and STEM concepts.** The content of these statements addresses how teacher educators should engage their students in discussing STEM concepts.	discussing STEM concepts associated with the activity or experience.
Distinguishing Between Engineering and Science Concepts	P4 T Sec3QS	They should be prepared to **distinguish between engineering and science concepts** and to understand how the two function to facilitate learning.	The panel members used the statement **distinguish between engineering and science concepts.** The content of these statements addresses how teacher educators should engage their students in distinguishing between engineering and science concepts.	distinguishing between engineering and science concepts.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Establishing Collaboration Between Science Teacher Educators and Technology and Engineering Teacher Educators	P7 T Sec3QS	These science educators must first have the engineering content and practices knowledge to know what to point out to their pre-service teachers. Many of the faculty training science teachers have no clue about teaching engineering and **do not want to collaborate** with engineering educators.	The panel members used the statement **do not want to collaborate.** The content of these statements addresses how teacher educators should engage their students in establishing collaboration between science teacher educators and technology and engineering teacher educators.	establishing collaboration between science teacher educators and technology and engineering teacher educators.
Examining the Engineering Design Process as a Content Method	P13 T Sec3QS	**Look** at the **engineering design** process as a pedagogically method, as well as a **content method.** I think science teachers need to see the wealth of opportunity to not only teach the "method" of design, but also the engaging way they can use the method as a pedagogically tool to transfer other content knowledge to the students.	The panel members used the statements **look, engineering design, and content method.** The content of these statements addresses how teacher educators should engage their students in examining the engineering design process as a content method.	examining the engineering design process as a content method.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Examining the Engineering Design Process as a Pedagogical Method	P13 T Sec3QS	**Look** at the **engineering design** process as a **pedagogically method**, as well as a content method. I think science teachers need to see the wealth of opportunity to not only teach the "method" of design, but also the engaging way they can use the method as a pedagogically tool to transfer other content knowledge to the students.	The panel members used the statements **look, engineering design, and pedagogically method.** The content of these statements addresses how teacher educators should engage their students in examining the engineering design process as a pedagogically method.	examining the engineering design process as a pedagogically method.
Exhibiting Techniques for Questioning Different Phenomena	P20 Sec3QS	**Exhibit techniques for questioning different phenomena.**	The panel members used the statements e**xhibit techniques for questioning different phenomena.** The content of these statements addresses how teacher educators should engage their students in exhibiting techniques for questioning different phenomena.	exhibiting techniques for questioning different phenomena.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Exposing Scientific Phenomena	P5 S Sec3QS	I view the addition of engineering practices to the standards in much the same way. We must engage our pre-service teachers in the process of identifying the key science content, **exposing** them to **scientific phenomena**, determining the questions and (now) engineering problems that put this content into real world contexts, and design investigative and/or engineering solutions that will increase our understanding of the content.	The panel members used the statement **exposing them to scientific phenomena.** The content of these statements addresses how teacher educators should engage their students in exposing student teachers to scientific phenomena.	exposing student teachers to scientific phenomena.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Focusing on a Limited Number of Concepts	P14 T Sec3QS	**Focus on a limited number of concepts**	The panel members used the statement f**ocus on a limited number of concepts.** The content of these statements addresses how teacher educators should engage their students in focusing on a limited number of concepts.	focusing on a limited number of engineering concepts.
Focusing on Broad Themes	P14 T Sec3QS	**Focus on broad themes** rather than atomistic competencies.	The panel members used the statement **focus on broad themes.** The content of these statements addresses how teacher educators should engage their students in focusing on broad themes.	focusing on broad themes rather than atomistic competencies.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Formative Assessment	P4 T Sec3QS	They should help students learn how to manage open-ended, group-oriented projects and how to **assess** the outcomes (both **formative** and summative).	The panel members used the statements **assess and formative.** The content of these statements addresses how teacher educators should engage their students in formative assessment.	formative assessment of open ended engineering problems.
Framing Design Activities as a Tool	P5 S Sec3QS	The key to intentionality is to continuously **frame the activities as a tool** for getting to the science content objectives of the NGSS standard we're addressing. The inquiry and the scientific process and the engineering design are all tools to engage student's brains in a way to accurately and completely conceptualize scientific content, and be able to employ it in the real world.	The panel members used the statement **frame the activities as a tool.** The content of these statements addresses how teacher educators should engage their students in framing design activities as a tool.	framing engineering design activities as a tool for getting to the science content objectives of the NGSS standard we're addressing.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Hands on/Minds on Problem Solving Activities	P19 S Sec3QS	**Hands on/minds on activities**	The panel members used the statement **Hands on/minds on activities.** The content of these statements addresses how teacher educators should engage their students in hands on/minds on problem solving activities.	hands on/minds on science activities.
Identifying Engineering Situations that Enable the Integration of Science Lessons	P16 S Sec3QS	Help pre-service teachers **identify eng situations**/scenarios that **enable the integration of science** content in their lesson/unit design	The panel members used the statements **identify engineering situations and enable the integration of science** The content of these statements addresses how teacher educators should engage their students in identifying engineering situations that enable the integration of science lessons.	identifying engineering situations that enable the integration of science lessons.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Identifying & Discuss Cross-Disciplinary Intersections Between Science, Technology, and Engineering Education	P7 T Sec3QS	They need to **intentionally point out** these **cross-disciplinary intersections** to their students when they occur. They can't assume students will make the connection.	The panel members used the statement **intentionally point out these cross-disciplinary intersections.** The content of these statements addresses how teacher educators should engage their students in identifying and discuss cross-disciplinary intersections between science, technology, and engineering education.	identifying and discuss cross-disciplinary intersections between science, technology, and engineering education.
Identifying Educational Objectives	P11 T Sec3QS	Make students **aware** of the e**ducational objectives:** what are key concepts to be learned?	The panel members used the statement **aware of the educational objectives.** The content of these statements addresses how teacher educators should engage their students in identifying educational objectives.	identifying educational objectives.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Identifying Key Science Content	P5 S Sec3QS	I view the addition of engineering practices to the standards in much the same way. We must **engage** our pre-service teachers in the process of **identifying the key science content**, exposing them to scientific phenomena, determining the questions and (now) engineering problems that put this content into real world contexts, and design investigative and/or engineering solutions that will increase our understanding of the content.	The panel members used the statements **engage and identifying the key science content.** The content of these statements addresses how teacher educators should engage their students in identifying key science content.	the process of identifying key science content.
Identifying STEM Concepts	P3 T Sec3QS	In this activity or experience, I would also require them to **identify** and discuss all important **STEM concepts** associated with the activity or experience.	The panel members used the statements **STEM concepts and identify.** The content of these statements addresses how teacher educators should engage their students in identifying STEM concepts.	identifying STEM concepts associated with the activity or experience.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Implementing Age & Grade Appropriate Engineering Design Challenges	P4 T Sec3QS	Teacher educators should provide opportunities for teacher education candidates to learn how to develop and facilitate the **implementation of age-appropriate engineering design challenges.**	The panel members used the statement **implementation of age-appropriate engineering design challenges.** The content of these statements addresses how teacher educators should engage their students in implementing age and grade appropriate engineering design challenges.	implementing age and grade appropriate engineering design challenges.
Inquiry Based Activities	P19 S Sec3QS	Instruction, problem based learning, **inquiry based activities**	The panel members used the statement **inquiry based activities.** The content of these statements addresses how teacher educators should engage their students in inquiry based activities.	inquiry based activities.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Inquiry Instruction	P5 S Sec3QS	The use of **inquiry instruction** and a focus on Nature of Science pedagogy in science classrooms has become common practice in science teacher preparation.	The panel members used the statement **inquiry instruction.** The content of these statements addresses how teacher educators should engage their students in inquiry instruction.	scientific inquiry instruction.
Instructing Students in the Use of Rubrics Such as the Dimensions of Success Tool to Measure Student Engagement	P8 S Sec3QS	There are several rubrics that measure how well teachers engage students in STEM activities, specifically engineering tasks. One such rubric or tool is the **Dimensions of Success (DoS)**.	The panel members used the statement **Dimensions of Success (DoS).** The content of these statements addresses how teacher educators should engage their students in instructing students in the use of rubrics such as the dimensions of success tool to measure student engagement.	the use of science rubrics such as the dimensions of success tool to measure student engagement.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Introducing Students to Technology and Engineering Organizations such as ITEEA & ASEE	P7 T Sec3QS	So that is the first problem, they need to bring in engineering educators and teach their students how to **collaborate** with engineering **educators** or where to find them (ex. **ITEEA, ASEE, etc.**)	The panel members used the statements **collaborate, educators and ITEEA, ASEE, etc...** The content of these statements addresses how teacher educators should engage their students in instructing students in introducing students to technology and engineering organizations such as ITEEA & ASEE.	introducing students to technology and engineering organizations such as ITEEA & ASEE.
Introducing Targeted Science Content through Guided Practice.	P2 T Sec3QS	Allow students to follow a '**guided practice**' that allows them to **introduce targeted science content** into their classroom.	The panel members used the statements **guided practice** and **introduce targeted science content** The content of these statements addresses how teacher educators should engage their students in introducing targeted science content through guided practice.	introducing targeted science content through guided practice.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Iterative Design Activities	P15 T Sec3QS	**Practice** the **iterative process** of design/re-design	The panel members used the statement pra**ctice the iterative process.** The content of these statements addresses how teacher educators should engage their students in iterative design activities.	iterative engineering design activities.
Judging Spatial Relationships	P1 T Sec3QS	**Judge spatial relationships** (e.g., Visualize how a system operates and mentally rotate system parts to solve problems within a given system.)	The panel members used the statement j**udge spatial relationships.** The content of these statements addresses how teacher educators should engage their students in judge spatial relationships.	judge spatial relationships, (e.g., visualize how a system operates and mentally rotate system parts to solve problems within a given system.)

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Lessons and Activities Where Students are Faced with an Engineering Problem	P17 S Sec3QS	**Lessons and activities** where students are **faced** with an **engineering problem**. Students define, and then learn, the science content needed to solve the problem.	The panel members used the statements **lessons and activities, faced and engineering problem.** The content of these statements addresses how teacher educators should engage their students in lessons and activities where students are faced with an engineering problem.	lessons and activities where students are faced with an engineering problem.
Lessons Where Science Content is Taught Through Engineering Practices	P17 S Sec3QS	Model **lessons where science content is taught through engineering practices** and makes it explicit to students that this was the approach and why/how it works.	The panel members used the statement **lessons where science content is taught through engineering practices.** The content of these statements addresses how teacher educators should engage their students in lessons where science content is taught through engineering practices.	lessons where science content is taught through engineering practices.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Making Comparisons	P1 T Sec3QS	**Make comparisons** (e.g., What commonalities and differences do systems have?)	The panel members used the statement **make comparisons.** The content of these statements addresses how teacher educators should engage their students in making comparisons.	making comparisons, (e.g., what commonalities and differences do systems have?)
Making Predictions	P1 T Sec3QS	**Predict** what should happen next (e.g., Based on what has been observed, what is known about a specific system, and what is known about related scientific principles, **make a prediction** about what will happen next.)	The panel members used the statement **predict. design activity and make a prediction.** The content of these statements addresses how teacher educators should engage their students in making predictions.	making predictions, (e.g., based on what has been observed, what is known about a specific system, and what is known about related scientific principles, make a prediction about what will happen next.)

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Managing Group-Oriented Projects	P4 T Sec3QS	They should help students learn how to **manage** open-ended, **group-oriented projects** and how to assess the outcomes (both formative and summative).	The panel members used the statements **manage and group-oriented project.** The content of these statements addresses how teacher educators should engage their students in managing group-oriented projects.	managing group-oriented projects.
Managing Open-Ended, Multiple Solution Problems	P4 T Sec3QS	They should help students learn how to **manage open-ended,** group-oriented **projects** and how to assess the outcomes (both formative and summative).	The panel members used the statements **manage and open-ended projects.** The content of these statements addresses how teacher educators should engage their students in managing open-ended, multiple solution problems.	managing open-ended, multiple solution problems.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Media Presentations Illustrating Design Activities	P11 T Sec3QS	**Use** short **video clips** or actual teaching sequences to illustrate how a master teacher USES the **design activity** to teach targeted science content	The panel members used the statements **use, design activity and video clips.** The content of these statements addresses how teacher educators should engage their students in media presentations illustrating design activities.	short video clips or actual teaching sequences to illustrate how a master teacher uses the design activity to teach targeted science content.
Modeling Integrating Science Teaching in Engineering Design	P16 S Sec3QS	**Model** how to **integrate science teaching** in **engineering design.**	The panel members used the statements **model and to integrate science teaching in engineering design.** The content of these statements addresses how teacher educators should engage their students in modeling integrating science teaching in engineering design.	modeling integrating science teaching in engineering design.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Participating in Lesson as Students	P16 S Sec3QS	**Engage** pre-service teachers **as K-12 students**	The panel members used the statements **engage and as K-12 students.** The content of these statements addresses how teacher educators should engage their students in participating in lessons as K-12 students.	participating in science lessons as K-12 students.
Problem Based Learning Activities	P19 S Sec3QS	Instruction, **problem based learning**, inquiry based **activities**	The panel members used the statements **problem based learning and activities.** The content of these statements addresses how teacher educators should engage their students in participating in problem based learning activities.	problem based learning activities.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Providing Engineering is Elementary and other Curriculum resources	P12 S Sec3QS	**Show curriculum** like **engineering is elementary** (or secondary version of this)	The panel members used the statements s**how curriculum and engineering is elementary.** The content of these statements addresses how teacher educators should engage their students in providing engineering are elementary and other curriculum resources.	providing engineering is elementary and other curriculum resources.
Providing Recourses such As Websites, Handouts, Expert Guest Speakers, Act.	P7 T Sec3QS	They should **provide** additional **resources** for their students to use for various content areas to better understand it and intentionally integrate it. Resources could be **websites, handouts, expert guest speakers, etc.**	The panel members used the statements **provide, resources and websites, handouts, expert guest speakers, etc...** The content of these statements addresses how teacher educators should engage their students in providing resources such as websites, handouts, expert guest speakers, ect.	providing resources such as websites, handouts, expert guest speakers, ect.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Recognizing Probable Outcomes	P1 T Sec3QS	**Recognize probable outcomes** (e.g., How will the system react to a specific action?)	The panel members used the statement r**ecognize probable outcomes.** The content of these statements addresses how teacher educators should engage their students in recognizing probable outcomes.	recognizing probable outcomes, (e.g., how will the system react to a specific action?)
Same Things Used to Teach Technology and Engineering Education Teachers	P6 T Sec3QS	The **same thing we teach technology and engineering teachers.**	The panel members used the statement **same thing we teach technology and engineering teachers.** The content of these statements addresses how teacher educators should engage their students in the same things used to teach technology and engineering teachers.	the same things used to teach technology and engineering teachers.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Science Specific Pedagogical Approaches	P5 S Sec3QS	Instructional strategies include both **science-specific pedagogical approache**s to engage the process of learning (e.g. the use of inquiry and modeling curriculum), and the continuous assessment of whether these approaches are progressing content knowledge identified in the NGSS standards. We model these practices for our pre-service teachers, who will then do them with their future students.	The panel members used the statement **science-specific pedagogical approaches.** The content of these statements addresses how teacher educators should engage their students in science-specific pedagogical approaches.	science-specific pedagogical approaches.
Scientific Arguments	P19 S Sec3QS	Discussions, **scientific argumentation**	The panel members used the statement **scientific argumentation.** The content of these statements addresses how teacher educators should engage their students in scientific argumentation.	scientific argumentation.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Summative Assessment	P4 T Sec3QS	They should help students learn how to manage open-ended, group-oriented projects and how to **assess** the outcomes (both formative and **summative)**.	The panel members used the statements **assess and summative.** The content of these statements addresses how teacher educators should engage their students in summative assessments.	summative assessments.
Teaching Sequences Utilizing Design Activities	P11 T Sec3QS	Use short video clips or actual **teaching sequences** to illustrate how a master teacher USES the design activity to teach targeted science content	The panel members used the statement **teaching sequences and design activity.** The content of these statements addresses how teacher educators should engage their students in teaching sequences utilizing design activities.	teaching sequences utilizing design activities.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Technological Problem Solving Techniques	P15 T Sec3QS	**Technological problem solving technique**	The panel members used the statement t**echnological problem solving techniques.** The content of these statements addresses how teacher educators should engage their students in technological problem solving techniques.	technological problem solving techniques.
Understanding Cause and Effect Relationships	P1 T Sec3QS	**Understand cause-effect relationships** (e.g., What parts of systems affect and are affected by other parts?)	The panel members used the statement **understand cause-effect relationships** The content of these statements addresses how teacher educators should engage their students in understanding cause and effect relationships.	understanding cause and effect relationships.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Understanding How Engineering and Science Concepts Function	P4 T Sec3QS	They should be prepared to distinguish between **engineering and science concepts and to understand** how the two **function** to facilitate learning.	The panel members used the statements **engineering and science concepts and to understand and function.** The content of these statements addresses how teacher educators should engage their students in understanding how engineering and science concepts function.	understanding how engineering and science concepts function.
Understanding Inquiry	P8 S Sec3QS	Teacher educators should share this instrument and help pre-service teachers **understand** how to best attend to each one, particularly student learning outcomes such as STEM engagement, STEM content learning, and **inquiry.**	The panel members used the statements **understand and inquiry.** The content of these statements addresses how teacher educators should engage their students in understanding inquiry.	understanding inquiry.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Understanding Science Concepts	P16 S Sec3QS	Teacher educators & pre-service student teachers must understand for themselves that if students don't have the **science content understandings** to address engage design, then they will be guessing at the cause of the problem, possible solution designs, etc.	The panel members used the statement **science content understandings.** The content of these statements addresses how teacher educators should engage their students in understanding science concepts.	understanding science concepts.
Understanding STEM Content Learning	P8 S Sec3QS	Teacher educators should share this instrument and help pre-service teachers understand how to best attend to each one, particularly student learning outcomes such as STEM engagement, **STEM content learning**, and inquiry.	The panel members used the statement **STEM content learning.** The content of these statements addresses how teacher educators should engage their students in understanding STEM content learning.	understanding STEMS content learning.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Understanding STEM Engagement	P8 S Sec3QS	Teacher educators should share this instrument and help pre-service teachers *understand* how to best attend to each one, particularly student learning outcomes such as **STEM engagement**, STEM content learning, and inquiry.	The panel members used the statement **STEM engagement.** The content of these statements addresses how teacher educators should engage their students in understanding STEM engagement.	understanding STEM engagement.
Understanding the Concepts of Engineering Design as in Described in the NGSS	P18 T Sec3QS	While **understanding** the science **content objective** to be met, engineering is one of those content areas in **NGSS.**	The panel members used the statements **understanding, content objective, and NGSS.** The content of these statements addresses how teacher educators should engage their students in understanding the concepts of engineering design as in described in the NGSS.	understanding the concepts of engineering design as in described in the NGSS.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing Continuous Assessment	P5 S Sec3QS	Instructional strategies include both science-specific pedagogical approaches to engage the process of learning (e.g. the use of inquiry and modeling curriculum), and the **continuous assessment** of whether these approaches are progressing content knowledge identified in the NGSS standards. We model these practices for our pre-service teachers, who will then do them with their future students.	The panel members used the statement **continuous assessment.** The content of these statements addresses how teacher educators should engage their students in utilizing continuous assessment.	utilizing continuous assessment.
Utilizing Professional Journals to Explore Teaching Pedagogies	P9 S Sec3QS	Assignments that send students into journals that explain what works and doesn't work in classroom settings where NGSS is being implemented.	The panel members used the statement a**ssignments that send students into journals.** The content of these statements addresses how teacher educators should engage their students in utilizing professional journals to explore teaching pedagogies.	utilizing professional journals to explore teaching pedagogies

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing Science to Solve Engineering Problems	P15 T Sec3QS	**Utilize scientific** physics, and chemistry principles for the basis of the design of a **solution to a problem**	The panel members used the statements **utilize scientific and solution to a problem.** The content of these statements addresses how teacher educators should engage their students in utilizing science to solve engineering problems.	utilizing science to solve engineering problems.
Utilizing STEM to Solve Social Problems	P14 T Sec3QS	Use authentic contexts the require **STEM understandings** to solve **problems** that have a **societal dimension** (e.g., making contaminated water potable; providing food for the expanding global population).	The panel members used the statements **STEM understandings, problems and societal dimensions.** The content of these statements addresses how teacher educators should engage their students in utilizing STEM to solve social problems.	utilizing STEM to solve social problems.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing the Engineering Design Process in Solving a Engineering/Technology Problem	P3 T Sec3QS	I would develop standards-based activities and experiences that require student to **apply** both **the engineering design process** and scientific method in the **solving an engineering/technology problem**	The panel members used the statements **apply both the engineering design process and solving an engineering/technology problem.** The content of these statements addresses how teacher educators should engage their students in utilizing the engineering design process in solving an engineering/technology problem.	utilizing the engineering design process in solving an engineering/technology problem.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing The Pedagogical Approach of Modeling Curriculum	P5 S Sec3QS	Instructional strategies include both science-specific pedagogical approaches to engage the process of learning (e.g. the use of inquiry and **modeling curriculum**), and the continuous assessment of whether these approaches are progressing content knowledge identified in the NGSS standards. We model these practices for our pre-service teachers, who will then do them with their future students.	The panel members used the statement **modeling curriculum.** The content of these statements addresses how teacher educators should engage their students in utilizing the engineering design process in utilizing the pedagogical approach of modeling curriculum.	utilizing the pedagogical approach of modeling science curriculum.

Section 3. Question 1E. Instructional Strategies (Sec3-QS)

Instructional Strategy	Panel #	Evidence	Rationale	Round 2 Statement
Utilizing The Pedagogical Approach of Scientific Inquiry	P5 S Sec3QS	Instructional strategies include both science-specific pedagogical approaches to engage the process of learning (e.g. the **use of inquiry** and modeling curriculum), and the continuous assessment of whether these approaches are progressing content knowledge identified in the NGSS standards. We model these practices for our pre-service teachers, who will then do them with their future students.	The panel members used the statement **use of inquiry.** The content of these statements addresses how teacher educators should engage their students in utilizing the engineering design process in utilizing the pedagogical approach of scientific inquiry.	utilizing the pedagogical approach of scientific inquiry.
Utilizing the Scientific Method in Solving a Engineering/Technology Problem	P3 T Sec3QS	I would develop standards-based activities and experiences that require student to apply both the engineering design process and **scientific method** in the **solving an engineering/technology problem**	The panel members used the statements **scientific method and solving an engineering/technology problem.** The content of these statements addresses how teacher educators should engage their students in utilizing the scientific method in solving an engineering/technology problem.	utilizing the scientific method in solving an engineering/technology problem.

Appendix K

Round 2 and 3 Rejected Items

Section 1. Question 1A. Practice 1 Rejected Competencies (Sec1-QA)

Question #	Rejected Competency (N=19)	Median	IQR
A-49	implement STEM learning experiences according to state standards.	7.0	2.00
A-25	determine which scientific questions may be addressed using engineering practices.	7.0	2.50
A-7	analyze STEM learning experiences regarding their focus on state curriculum standards.	7.0	2.50
A-18	define the meaning of scientific inquiry.	7.0	2.75
A-76	understand the vocation of engineering.	7.0	3.00
A-24	prepare teaching materials that provide contextual clues to engineering based problems.	7.0	3.75
A-52	make scientific observations to formulate multiple ideas, questions and problems related to those observations.	7.0	4.00
A-58	take risk when solving engineering problems.	7.0	4.00
A73	understand how to teach science content.	7.0	4.00
A-78	utilize an iterative design process to solve societal problems.	7.0	4.00
A-13	read engineering design problems for contextual clues.	6.5	3.50
A-45	identify the technology and engineering concepts of each in the STEM fields.	6.5	3.75
A-68	understand Disciplinary Core Ideas.	6.0	2.00
A71	understand the Framework for K-12 Science Education.	6.0	3.50
A-75	understand scientific inquiry.	6.0	4.00
A63	understand computational thinking.	5.0	0.75

Section 1. Question 1A. Practice 1 Rejected Competencies (Sec1-QA)

Question #	Rejected Competency (N=19)	Median	IQR
A53	meet the institutional goals of sustainability.	5.0	4.00
A-74	understand the shifts in NGSS as indicated in the Framework of K-12 Science Education.	5.0	4.00
A14	define what computational thinking is.	3.0	4.00

Section 1. Question 2B. Practice 1 Rejected Strategies (Sec1- QB)

Question #	Rejected Strategy (N=31)	Median	IQR
B-38	discussing engineering case studies.	7.0	2.50
B-54	introducing educational resources such as the NGSS.	7.0	2.50
B-21	defining scientific questions.	7.0	3.00
B-77	researching the engineering design processes.	7.0	3.00
B-102	writing lessons focusing on modeled pedagogy.	7.0	3.25
B-83	using argumentation skills.	7.0	3.25
B-84	using case studies.	7.0	3.25
B-99	utilizing peer sharing to present findings in an effective manner.	7.0	3.75
B-18	contextualizing scientific phenomena to determine whether it involves a problem of engineering design.	7.0	4.00
B-27	design-based pedagogical approaches intentionally to teach the content and practices of science and mathematics education through the content and practices of technology/engineering education.	7.0	4.00
B-55	isolated scientific phenomena to determine if it involves engineering design problem.	7.0	4.00
B-100	utilizing peer sharing.	6.5	4.00
B-66	peer evaluations of curriculum focused on the defining of engineering problems.	6.0	1.25

Section 1. Question 2B. Practice 1 Rejected Strategies (Sec1- QB)

Question #	Rejected Strategy (N=31)	Median	IQR
B-70	presentations using scientific models.	6.0	2.25
B-57	facilitated science and engineering lessons.	6.0	3.50
B-86	using data collection.	6.0	3.50
B-51	identifying science questions.	6.0	4.00
B-68	presentations on scientific phenomena.	5.5	2.50
B-75	reading the K-12 science Framework.	5.5	3.25
B-65	participating in science lessons as students.	5.5	3.50
B-40	peer discussions on the conceptual shifts of K-12 Science Framework.	5.5	3.75
B-41	distinguishing science problems that require engineering solutions.	5.5	3.75
B-8	creating authentic science activities.	5.5	4.00
B-37	differentiating problem based learning and project based learning.	5.0	2.50
B-60	making scientific models.	5.0	2.75
B-69	presentations using scientific experiences.	5.0	3.25

Section 1. Question 2B. Practice 1 Rejected Strategies (Sec1- QB)

Question #	Rejected Strategy (N=31)	Median	IQR
B-62	modeling scientific inquiry practices.	5.0	3.50
B-79	scientific inquiry activities.	5.0	4.00
B-16	computational thinking science activities.	3.5	3.50
B-61	modeling the utilization of science materials.	3.0	4.00

Section 2. Question A. Practice 6 Rejected Competencies (Sec2 -QA)

Question #	Rejected Competency (N=18)	Median	IQR
A-29	design engineering solutions to a science problem.	7.0	1.25
A-60	model a variety of virtual engineering skills.	7.0	1.25
A-8	utilize debugging to solve engineering problems.	7.0	1.75
A-11	adapt prior technologies.	7.0	2.25
A-49	implement inquiry-based science pedagogies.	7.0	2.25
A-1	explain science problems in written form.	7.0	3.00
A-56	meet institutional goals of sustainability.	7.0	3.00
A-20	combine techniques of engineering problem in an effort to solve it.	7.0	3.25
A-26	demonstrate aesthetic quality in engineering solutions.	7.0	3.25
A-74	understand technical writing.	7.0	3.25
A-36	identify alternative uses of engineering materials.	7.0	3.50
A-57	model a variety of analytical engineering skills.	7.0	3.50
A-59	model a variety of physical engineering skills.	7.0	4.00
A-80	complete computer aided design drawings of proposed solutions.	7.0	4.00
A-24	define science content in engineering problems.	6.5	4.00
A-18	augment engineering problems in an effort to solve it.	6.0	2.00

Section 2. Question A. Practice 6 Rejected Competencies (Sec2 -QA)

Question #	Rejected Competency (N=18)	Median	IQR
A-12	add additional content to and engineering problem in an effort to find a solution.	6.0	2.50
A-52	incorporate alternative materials to solve engineering problems.	6.0	3.00

Section 2. Question B. Practice 6 Rejected Strategies (Sec2 -QB)

Question #	Rejected Strategy (N=6)	Median	IQR
B-24	engineering activities that requiring debugging.	7.0	2.50
B-9	concurrent engineering activities.	7.0	2.50
B-43	incorporating design activities into case study exploration and resolution.	7.0	3.25
B-54	representation modeling	7.0	3.25
B-34	group facilitation.	7.0	3.50
B-75	writing lessons for engineering applications of science content.	7.0	3.50

Section 3. Question 1E. Rejected Instructional Strategies (Sec3-Q Strategies)

Question #	Rejected Instructional Strategies (N=7)	Median	IQR
E43	scientific inquiry instruction.	7.0	1.50
E4	approaching engineering as a way of doing.	7.0	2.50
E-46	introducing targeted science content through guided practice.	7.0	2.50
E-21	developing situational awareness of malfunctioning systems in operation to determine what is not working correctly.	7.0	3.00
E-48	judge spatial relationships, (e.g., visualize how a system operates and mentally rotate system parts to solve problems within a given system.)	7.0	3.50
E-32	focusing on broad themes rather than atomistic competencies.	7.0	4.00
E-81	utilizing the pedagogical approach of scientific inquiry.	7.0	4.00

Appendix L

Round 2 Non-Consensus Items

Round 2 (Sec1-QA) Practice 1 Non-Consensus Competencies (N=19)

Question #	Non-Consensus Competencies	IQR	Mode/Modes
A-50	implement technology and engineering instructional methods.	4.25	8
A-40	identify engineering problems that require engineering solutions.	4.75	10
A-5	explain engineering design problems in written form.	4.75	9
A-48	implement design based instructional methods in technology and engineering and STEM focused curricular applications.	4.75	5,8,9, 10
A-55	model ethical research procedures.	5.00	10
A-71	understand the Framework for K-12 Science Education.	5.00	2, 5, 7, 8
A-63	understand computational thinking.	5.00	5
A-53	meet the institutional goals of sustainability.	5.00	5, 7
A-70	understand engineering problems.	5.25	10
A-17	define a science problem.	5.25	10
A-11	assess student understanding of inquiry, scientific processes and computational thinking through observations.	5.50	7,8,10
A-2	explain engineering problems.	6.00	10
A-32	facilitate student development in engineering design practices.	6.00	9
A-73	understand how to teach science content.	6.00	9
A-34	work in small cooperative groups.	6.25	10

Round 2 (Sec1-QA) Practice 1 Non-Consensus Competencies (N=19)

Question #	Non-Consensus Competencies	IQR	Mode/Modes
A-14	define what computational thinking is.	6.25	1, 4, 5, 8
A-1	do hands on investigations to gather insights/information about engineering design challenges.	6.75	3, 10
A-23	design instructional environments that accommodate inquiry-based pedagogies.	6.75	10
A-10	apply STEM pedagogical concepts, in design, technology and engineering education in STEM focused curricular models.	7.75	9

Round 2 (Sec1-QB) Practice 1 Non-Consensus Instructional Strategies (N=26)

Question #	Non-Consensus Instructional Strategies	IQR	Mode/Modes
B27	design-based pedagogical approaches intentionally to teach the content and practices of science and mathematics education through the content and practices of technology/engineering education.	4.25	5, 9, 10
B19	cooperative learning activities.	4.25	10
B32	developing knowledge of technical skills.	4.25	10
B66	peer evaluations of curriculum focused on the defining of engineering problems.	4.25	6
B94	using summative assessments to evaluate students' design practices, final prototypes and mastery of relevant STEM ideas.	4.25	10
B56	keeping a journal.	4.25	6
B91	using instructional strategies to monitor student progress of engineering design concepts.	4.50	10
B80	teaching mini engineering lessons to their peers	4.50	10
B30	designing technical devices to solve engineering problems.	4.50	6, 10
B52	identifying the vocation of engineering.	4.50	8
B100	utilizing peer sharing.	4.50	5, 7, 9
B8	creating authentic science activities.	4.50	6, 8
B60	making scientific models.	4.50	5
B61	modeling the utilization of science materials.	4.50	2
B85	using data analysis.	4.75	5, 10
B24	demonstrating ethical research procedures.	4.75	7
B96	cooperative learning activities so students can see how teams are vital to the success of an engineering project.	5.00	10
B13	collaborative engineering learning activities.	5.25	10
B87	using differentiated instruction to teach engineering design.	5.25	9

Round 2 (Sec1-QB) Practice 1 Non-Consensus Instructional Strategies (N=26)

Question #	Non-Consensus Instructional Strategies	IQR	Mode/Modes
B101	utilizing science content to work through engineering models.	5.25	4, 7, 10
B90	using hands on learning experiences in students own discipline (bio, Chemistry, physics).	5.50	10
B11	collaborative critique of engineering design resources.	5.50	10
B37	differentiating problem based learning and project based learning.	5.50	3
B25	describing the purpose of integrative STEM education.	7.25	10
B89	group discourse.	7.25	2, 7
B95	concept mapping.	7.50	5, 9, 10

Round 2 (Sec1-QA) Practice 6 Non-Consensus Competencies (N=18)

Question #	Non-Consensus Competencies	IQR	Mode/Modes
A-4	choose an engineering design solution.	4.25	10
A-65	support interdisciplinary collaborations.	4.25	10
A-19	combine elements of engineering problem in an effort to solve it.	4.25	5, 10
A-64	sketch and complete finished technical drawings.	4.25	9
A-55	manage student behaviors.	4.50	10
A-46	identify values to solve an engineering problem.	4.50	4, 7, 8, 10
A-60	model a variety of virtual engineering skills.	4.50	7
A-74	understand technical writing.	4.50	3, 7
A-1	explain science problems in written form.	4.50	7
A-8	utilize debugging to solve engineering problems.	4.75	7, 10
A-20	combine techniques of engineering problem in an effort to solve it.	4.75	7, 10
A-15	apply design, engineering and technology literacy standards in the design and implementation of DTE learning activities.	5.00	8
A-18	augment engineering problems in an effort to solve it.	5.00	6, 10
A-49	implement inquiry-based science pedagogies.	5.00	3, 5, 7, 8
A-58	model collaborative brainstorming skills.	5.25	9, 10
A-34	understand idea-generating strategies.	6.00	3, 8, 9
A-14	apply contextual reading skills.	6.00	8
A-56	meet institutional goals of sustainability.	7.50	7

Round 2 (Sec2-QB) Practice 6 Non-Consensus Instructional Strategies (N=11)

Question #	Non-Consensus Competencies	IQR	Mode/Modes
B-60	technical drawings.	4.25	6
B-54	representation modeling	4.50	7
B-45	modeling visualization techniques.	4.50	9
B-53	reflecting on key scientific concepts identified and conceptual shifts in NGSS.	4.50	6, 9
B-4	building arguments from evidence.	4.50	10
B-5	building technical devices.	4.50	10
B-72	utilizing concept mapping.	4.75	2, 4, 8
B-33	facilitated lessons.	5.00	8, 10
B-70	utilizing media presentations to show examples of collaborative work skills in engineering design as well as to present their findings.	5.25	10
B-18	lesson planning.	5.75	10
B-8	Computer Aided Design.	6.00	10

Round 3 (Sec2-Q Strategies) Instructional Strategies (N=11)

Question #	Non-Consensus Instructional Strategies	IQR	Mode/Modes
S-73	understanding STEM engagement.	4.25	10
S-68	understanding cause and effect relationships.	4.25	10
S-76	Utilizing professional journals to explore teaching pedagogies.	4.25	9, 10
S-4	approaching engineering as a way of doing.	4.25	7, 10
S-10	cooperative learning.	4.25	10
S-31	focusing on a limited number of engineering concepts.	4.50	0, 5, 6
S-82	utilizing the scientific method in solving a engineering/technology problem.	4.75	1, 6, 10
S-27	examining the engineering design process as a content method.	5.25	9, 10
S-59	providing engineering is elementary and other curriculum resources.	5.50	10
S-70	understanding inquiry.	5.50	10
S-43	scientific inquiry instruction.	5.50	7
S-79	utilizing the engineering design process in solving an engineering/technology problem.	6.50	10
S-45	introducing students to technology and engineering organizations such as ITEEA & ASEE.	6.75	10

Appendix M

Round 3 Non-Consensus Stable Items

Section 1. Question 1A. Practice 1 Competency (Sec1-QA)

Question #	Round 3 Non-Consensus Stable Competency (N=8)	R3 Median	R2 IQR	R3 IQR	IQR Change
A-40	identify engineering problems that require engineering solutions.	9.0	4.75	4.75	0
A-55	model ethical research procedures.	9.0	5.00	4.50	-0.50
A-10	apply STEM pedagogical concepts, in design, technology and engineering education in STEM focused curricular models.	8.0	7.75	7.00	-0.75
A-34	work in small cooperative groups.	8.0	6.25	6.25	0
A-11	assess student understanding of inquiry, scientific processes and computational thinking through observations.	7.0	5.50	5.25	-0.25
A-17	define a science problem.	7.0	5.25	4.50	-0.75
A-23	design instructional environments that accommodate inquiry-based pedagogies.	6.5	6.75	5.75	-1.00
A-1	do hands on investigations to gather insights/information about engineering design challenges.	4.0	6.75	6.25	-0.50

Section 1. Question 2B. Practice 1 Strategy (Sec1- QB)

Question #	Round 3 Non-Consensus Stable Strategies (N=12)	R3 Median	R2 IQR	R3 IQR	IQR Change
B-96	cooperative learning activities so students can see how teams are vital to the success of an engineering project.	9.0	5.00	5.00	0
B-87	using differentiated instruction to teach engineering design.	8.5	5.25	5.25	0
B-19	cooperative learning activities.	8.0	4.25	4.25	0
B-11	collaborative critique of engineering design resources.	7.5	5.50	4.25	-1.25
B-24	demonstrating ethical research procedures.	7.3	4.75	4.50	-0.25
B-30	designing technical devices to solve engineering problems.	7.0	4.50	4.25	-0.25
B-89	group discourse.	7.0	7.25	4.50	-2.75
B-85	using data analysis.	6.8	4.75	4.50	-0.25
B-25	describing the purpose of integrative STEM education.	6.6	7.25	6.50	-0.75
B-101	utilizing science content to work through engineering models.	6.5	5.25	5.25	0
B-52	identifying the vocation of engineering.	6.0	4.50	5.50	1.00
B-95	concept mapping.	5.0	7.50	7.25	-0.25

Section 2. Question A. Practice 6 Competency (Sec2 -QA)

Question #	Round 3 Non-Consensus Stable Competency (N=3)	R3 Median	R2 IQR	R3 IQR	IQR Change
A-34	understand idea-generating strategies.	8.0	6.00	4.75	-1.25
A-14	apply contextual reading skills.	7.0	6.00	6.00	0
A-19	combine elements of engineering problem in an effort to solve it.	7.0	4.25	4.25	0

Section 2. Question B. Practice 6 Strategy (Sec2 -QB)

Question #	Round 3 Non-Consensus Stable Strategies (N=7)	R3 Median	R2 IQR	R3 IQR	IQR Change
B-4	building arguments from evidence.	10.0	4.50	4.25	-0.25
B-45	modeling visualization techniques.	7.5	4.50	4.50	0
B-60	technical drawings.	7.5	4.25	4.50	0.25
B-70	utilizing media presentations to show examples of collaborative work skills in engineering design as well as to present their findings.	7.5	5.25	6.00	1.25
B-8	Computer Aided Design.	7.0	6.00	4.75	-1.25
B-53	reflecting on key scientific concepts identified and conceptual shifts in NGSS.	6.0	4.50	4.50	0
B-72	utilizing concept mapping.	4.5	4.75	4.25	-1.00

Section 3. Instructional Strategies (Sec3-Q Strategies)

Question #	Round 3 Non-Consensus Stable Strategies (N=4)	R3 Median	R2 IQR	R3 IQR	IQR Change
S-45	introducing students to technology and engineering organizations such as ITEEA & ASEE.	10.0	6.75	5.25	-1.50
S-59	providing engineering is elementary and other curriculum resources.	9.0	5.50	5.00	-0.50
S-31	focusing on a limited number of engineering concepts.	5.5	4.50	4.25	-0.25
S-82	utilizing the scientific method in solving a engineering/technology problem.	5.0	4.75	6.00	1.25