A qualitative assessment of preservice elementary teachers' formative perceptions regarding engineering and K-12 engineering education

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A qualitative assessment of preservice elementary teachers’ formative perceptions regarding engineering and K-12 engineering education

by

Dennis Eugene Culver

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Education (Curriculum and Instructional Technology)

Program of Study Committee:
Constance P. Hargrave, Co-major Professor
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Iowa State University
Ames, Iowa
2012

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Current teacher education programs provide limited instruction for preservice elementary teachers regarding the incorporation or teaching of engineering concepts and skills in their classrooms. Few studies have been conducted that focus specifically on preservice elementary teachers’ formative perceptions and receptivity towards engineering education. That is, not enough is known about what preservice teachers know and think about engineering.

The purpose of this qualitative research study was to investigate how forty-four preservice elementary teachers’ from a large Midwestern university approached engineering design, the perceptions of engineering and K-12 engineering education that they possessed, and their level of receptiveness with regards to K-12 engineering education. Data were collected using a demographic survey, journal entries, observations, and focus group discussions. The written, verbal, and visual data collected in this study were analyzed using conventional qualitative content analysis, which consisted of inductively developing categories and codes after repeatedly examining the data.

The results of the study indicate that the preservice elementary teachers did not utilize any deliberate design process when engaged in a design task. Engineering was perceived as being synonymous with construction and that engineering design consists of trial and error. Participants envisioned their students succeeding in engineering due to their students’ prior knowledge, not necessarily the actions of themselves as the teacher. With regards to receptivity, participants expressed apprehension and optimism along with fear and pessimism. Tangential factors also impacted the receptivity of participants.
CHAPTER 1. INTRODUCTION

The American Society for Engineering Education (ASEE) states that “though people spend 95% of their time interacting with the human-made world, few can articulate how our designed world came to be and how the products that we have developed to meet our needs function” (ASEE, 2006). This sentiment expresses a concern shared by many groups today. The ASEE, along with the National Academy of Engineering and leaders in government, education, and business are worried that the current education system in the U.S. fails to provide K-12 students with the opportunities that may lead them to choose engineering as a career or, at the very least, a better understanding and appreciation of the field.

The purpose of this chapter is to provide an overview for the research study about preservice elementary teachers perceptions of engineering and K-12 engineering education. This chapter begins by first explaining the rationale behind K-12 engineering education, current standards associated with K-12 engineering education, and the approaches that may be used to implement K-12 engineering curricula. After this, a brief review of the literature is provided, followed by a discussion focusing on engineering education in the elementary classroom. Next, the statement of the research problem, the purpose of the study, and the research questions are provided. This is followed by an overview of the research methodology and data analysis used for the study. The chapter concludes by discussing the limitations of the study and defining specific terms used throughout the remaining chapters.

Rationale for K-12 Engineering Education

The conventional rationale for engineering education at the K-12 level primarily focuses on individual and national economic utility. That is, increasing the number of people who choose engineering as a career and increasing the ability of the United States to remain
competitive in a global society. (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Locke, 2009; Nugent, Kunz, Rilett, & Jones, 2010; Pinelli & Haynie, 2010; Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, & Kimmel, 2010) While these are valid reasons to support engineering in the K-12 environment, it could be argued that the purpose of school goes beyond mere economic utility (Postman, 1996). Katehi, Pearson, and Feder (2009) go beyond the conventional rationale and state the importance of engineering design and technological literacy. They argue that a K-12 curriculum infused with engineering concepts may provide a way for students to understand and engage in engineering design and increase their understanding of technology and its impact on society. Furthermore, engineering design provides a real-world context for abstract concepts that students may otherwise not understand. Technological literacy “encompasses three interdependent dimensions – knowledge, ways of thinking and acting, and capabilities” with the goal being “to provide people with the tools to participate intelligently and thoughtfully in the [technological] world around them” (Pearson & Young, 2002, p. 3). Engineering design and technological literacy take the need for K-12 engineering education beyond careers and economics to understanding how the world is designed, why it is designed that way, and how design decisions affect us all. Furthermore, incorporating engineering education at the K-12 level can promote a new, critical way of thinking that examines the natural and designed world.

Constructionist learning theory provides further support for engineering education. Constructionism served as the theoretical foundation for Seymour Papert’s work with the Logo programming language (Kafai & Resnick, 1996). According to Papert and Harel (1991), constructionism is similar to Piaget’s constructivism in that both envision learning as individuals building personally meaningful knowledge structures. However, constructionist
learning theory goes beyond constructivism by adding the idea that learning “happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity” (Papert & Harel, 1991, p. 1) and emphasizes artifacts, asserting “that meaning construction happens particularly well when learners are engaged in building external and sharable artifacts” (Kafai & Resnick, 1996, p. 4). The construction of these external artifacts provides rich contexts in which students can learn. Constructionist learning theory provides a theoretical rationale for incorporating engineering in the K-12 curriculum due to its emphasis on learning by designing artifacts.

**K-12 Engineering Education Standards**

Whatever the rationale for K-12 engineering education, the practicalities of such a curriculum are still very much in development. Currently the International Technology and Engineering Educators Association (ITEEA) and the National Science Education Standards (NSES) provide the only description of engineering content to be taught according to grade level. Currently the NSES do not provide explicit engineering education standards, but they do provide a general connection to engineering. For example, the “Science in Personal and Social Perspectives Standards” state that K-4 students should be able to distinguish between natural objects and objects made by humans as well as understand the abilities of technological design. Standards for grades 5-8 also call for an understanding of technological design and understanding of the relationship between science and technology (National Research Council, 1996). Despite the grade band separation, there is little difference among grade levels in the NSES. However, engineering will have a much more prominent position in the next iteration of the National Science Education Standards (NRC, 2011). The ITEEA has been much more specific about the engineering and technology concepts students should
learn at each grade level. Standards eight through thirteen of ITEEA’s Standards for Technological Literacy (2007) provide explicit information on what engineering concepts should be introduced at what grade level (See Appendix A).

While the ITEEA Standards for Technological Literacy provide educators with direction about what to teach each grade level, it is important to note that engineering standards, and standards in general, may not be that beneficial. A study conducted by the Committee on Standards for K-12 Engineering Education, at the direction of National Research Council (NRC, 2010), found that while it may be possible to develop national K-12 engineering standards, their effectiveness would be limited. This is due to: limited experience with engineering in K-12 schools in the U.S.; the lack of qualified teachers to provide engineering education; the lack of evidence supporting standards-based educational reforms; and overcrowded curricula (NRC, 2010). The researchers suggested infusing engineering concepts into already established content areas such as math and science or mapping engineering concepts into pre-existing standards in other content areas (NRC, 2010).

**Engineering Design**

The National Science Education Standards and the ITEEA’s Standards for Technology Literacy provide a way for engineering to be mapped to existing K-12 content standards. Both sets of standards focus on presenting engineering as a design process. Scholars agree that the engineering design process is central to K-12 engineering education (Asunda & Hill, 2008; Denson, Kelley & Wicklein, 2009; Hill, 2006; Katehi, Feder & Pearson, 2009; Linnell, 2007; Locke, 2009; Smith & Burghardt, 2007). Engineering design is the approach engineers use to determine the best way to construct a device or process that serves a specific purpose (Katehi, Pearson & Feder, 2009). Throughout this thesis, the term
“engineering design” is used frequently. While there is general agreement that the engineering design process is the key element to engineering education, there are many views on what is included in the process and the knowledge that is required to participate in engineering design. For example, Gattie and Wicklein (2007) argue that engineering design must include appropriate mathematical analyses while Papert and Harel (1991) focus on the importance of prototyping and constructing artifacts. What is meant by engineering design can also vary depending on the content being taught, the environment it is being taught in, and the methods being used to teach it.

**Implementing the K-12 Engineering Curriculum: Engineering Content, Context, and Pedagogy**

When it comes to the implementation of K-12 engineering curricula, there are three approaches one may use. These three approaches can each be used as ways to address how to implement engineering education. Each may be used individually or they may be used in combination. The first approach is content. Engineering content includes directly teaching the concepts and skills that are foundational to engineering. The second approach is engineering context. This involves using engineering as a context for teaching subjects such as science and math. Engineering content can still be present, but it is secondary to the math or science content being taught. The third approach is engineering pedagogy. An engineering pedagogy involves the use of specific teaching strategies that support the acquisition of engineering content and uses engineering context to support ways of thinking that are consistent with engineering epistemology.
Engineering Content

A commonly advocated approach to K-12 engineering education is to teach engineering content, including both concepts and skills, to K-12 students. Project Lead the Way (PLTW, 2011) is an example of a curriculum that emphasizes engineering content. PLTW explicitly teaches the engineering design process and focuses on content specific to the domain of engineering.

While engineering design is viewed as a key concept in K-12 engineering education, there are differences regarding what the engineering design process entails. Silk and Schunn (2008) view systems (i.e. understanding the relationship between structure, behavior, and function) and design optimization as the two fundamental components of engineering design. In contrast, Petrosino, Svihla, and Brophy (2008) focus on developing skills related to drawing and creating representations as well as experimenting and testing. Mathematical analysis and modeling are two additional components of engineering design that have been addressed to varying degrees in K-12 engineering education (Katehi et al., 2009). After reviewing several K-12 engineering curricula, Katehi et al. (2009) found that modeling and mathematical analysis were rarely included in the engineering design process. Gattie and Wicklein (2007) argue that mathematical analysis must be included if a design process is to truly be an “engineering” design process. The nature of the engineering design process is also influenced by the instructional environment in which it occurs.

Engineering Context

Engineering context is another approach to implementing a K-12 engineering education curriculum. Using engineering as a context involves teaching content that is embedded in a meaningful engineering design problem with a clear purpose that requires the
use of the systematic engineering design process. Although a singular definition is not provided (Katehi, Pearson & Feder, 2009), the critical element to an engineering context is the nature of the problem. This design problem should be tied to the real world, embedded in the iterative and systematic engineering design process, complex enough to allow for multiple solution paths, and require teamwork (Jonassen, 2000). Providing an engineering context for learning subjects such as science and math has been the goal of several popular curricula. Examples of such curricula include Engineering is Elementary from the Boston Museum of Science (EiE, 2011) and Design and Discovery from Intel Corporation (Intel Education, 2011). While these curricula attempt to provide an engineering context, they are not always successful. The focus on engineering context can easily shift to a focus on engineering content if the teacher lacks knowledge and skill in maintaining the engineering context.

**Engineering Pedagogy**

Engineering pedagogy includes the methods and practices teachers use to engage students in the nature and habits of mind of engineering. This approach encompasses both engineering content and context. Engineering pedagogy can be a way to promote engineering as a way of thinking or a way to view and critique the world (Katehi, Pearson & Feder, 2009). For example, engineering can be used to promote a “world view in which possibilities and opportunities can be found in every challenge and an understanding that every technology can be improved” (Katehi, Pearson & Feder, 2009, p. 152). Such pedagogy can be used to critically examine our society and ask questions regarding the ethics of engineering, who can be an engineer, and the social implications of the devices, systems, and
processes engineers produce. Currently the literature provides little guidance on specific principles on engineering pedagogy.

While content, context, and pedagogy as individual ways to implement K-12 engineering education have been neatly separated here, such neat separation is not mirrored in reality. The pedagogy used depends heavily on the way the learning context is structured as well as the nature of the content being taught. Content can also influence how the context is structured. Shulman (1986) emphasized this point with his discussion of teacher pedagogical content knowledge (PCK). By PCK he meant understanding “the ways of representing and formulating the subject that make it comprehensible to others.” (Shulman, 1986, p. 9) This includes understanding what is easy or difficult about content topics and what common misconceptions students may possess. While knowledge is critical in determining the difficulty of a topic and identifying misconceptions, perception can influence how and when such knowledge is used.

**Perceptions of Engineering and K-12 Engineering Education**

There have been few studies conducted that ascertain the knowledge and understanding the general public and educators possess regarding engineering. In this section a brief review of studies that examined the engineering knowledge of the general population, inservice teachers and preservice teachers is provided.

Regardless of whether participants were members of the general public (NAE, 2008), inservice educators (Lambert et al. 2007; ASEE, 2006) or preservice educators (Gallager, 2004) the responses to the questions “What is engineering?” and “What do engineers do?” predominantly focused on engineering being similar to construction. The literature indicates that both the public and educators strongly associate engineering with skill in mathematics
and science (NAE, 2008; ASEE, 2005; ASEE, 2006; Lambert, 2007). Educators in other studies believed that engineers lack speaking, writing, and social skills (Davis & Gibbin, 2002; Yasar, Baker, Robinson-Kurpius, Krause, & Roberts, 2006). These findings indicate that engineers are perceived to be proficient in math and science but lack social and communication skills.

In their examination of educators, Yasar et al. (2006) found that beginning inservice teachers were more receptive to design, engineering, and technology (DET) than more experienced inservice teachers because teacher education programs in recent years have begun emphasizing the National Science and National Technology Standards. According to Yasar et al. (2006), this places preservice teachers in a favorable position to think about how engineering concepts align with these standards. Engineering content and pedagogy could serve as a foundation for preservice teachers as they learn how to teach science, math and technology concepts and develop their understanding of how these content areas are related to each other.

The research literature also shows that the degree to which inservice and preservice educators believe engineering education is important depends on teaching experience, preservice education, grade level, and subject area (ASEE, 2005; Baker, Yasar-Purzer, Robinson-Kurpius, Krause, & Roberts, 2007; Lambert, Diefes-Dux, Beck, Duncan, Oware, & Nemeth, 2007; Yasar et al., 2006; Hudson, English, & Dawes, 2009). Experienced teachers in science, math, and technology found engineering education to be important (ASEE, 2005; Baker et al., 2007; Lambert et al., 2007). However, the study conducted by Yasar et al. (2006) indicated that more experienced science teachers were less interested in learning about engineering education. Middle and secondary teachers were more likely to
believe that engineering education is important compared to elementary teachers (Yasar et al., 2006; ASEE, 2005; Hudson et al., 2009). Despite of these findings, scholars have argued that the elementary classroom environment is an essential context for implementing K-12 engineering education (Petroski, 2003; Brophy, Klein, Portsmore & Rogers, 2008).

Engineering Education for the Elementary Classroom

Engineering education is typically targeted for middle and secondary students as the teachers for these grades have expressed the most knowledge and interest in engineering (Yasar et al., 2006). Yasar et al. (2006) found that elementary teachers were the least interested in design, engineering, and technology concepts. This was due to elementary teachers being content generalists teaching math, science, language arts, reading and social studies as opposed to middle or high school teachers who are content specialists. In contrast, Petroski (2003) argues that young children “experience the essence of engineering in their earliest activities” and “design is rooted in choice and imagination – and play. Thus the essential idea of engineering can be readily explained to and understood by children” (p. 206). Brophy, Klein, Portsmore and Rogers (2008) echo this position by stating, "Engineering activities and goals are not trivial and can be intrinsically motivating because they engage a natural desire to make something and they tap into the curiosity that comes from wanting to learn how things work" (p. 371).

According to Brophy et al. (2008), engineering design tasks are motivating for young students and it is important that such tasks begin early on in a student’s educational career. Elementary and middle school educators have a huge influence on how students see themselves in science, technology, engineering, and mathematics (STEM) roles and how they perceive the STEM fields. Cultivating qualities of engineering problem solving and design,
and modeling inquiry processes for young learners does us all a great service as we prepare for the future (Brophy et al., 2008).

The research literature provides few studies that have examined how educators understand and perceive engineering and engineering education. What is known is that engineering is typically viewed positively despite people not fully understanding what engineering is (Davis & Gibbin, 2002; NAE 2008). Engineering is commonly misunderstood as construction and engineers are viewed in stereotypical ways (NAE, 2008; ASEE, 2005; ASEE, 2006; Lambert, 2007; Davis & Gibbin, 2002; Yasar, Baker, Robinson-Kurpius, Krause, & Roberts, 2006). The research literature also indicates that the degree to which educators believe engineering education is important depends on teaching experience, preservice education, grade level, and subject area (ASEE, 2005; Baker, Yasar-Purzer, Robinson-Kurpius, Krause, & Roberts, 2007; Lambert, Diefes-Dux, Beck, Duncan, Oware, & Nemeth, 2007; Yasar et al., 2006; Hudson, English, & Dawes, 2009). Elementary teachers were the most likely to express little interest in engineering (Yasar et al., 2006; ASEE, 2005; Hudson et al., 2009). This is a concern because cultivating qualities of engineering education in young learners does the nation a great service as we prepare for a future where skills in the STEM subjects are required. (Brophy et al., 2008).

**Statement of the Problem**

Current teacher education programs do not prepare elementary teachers to incorporate or teach engineering concepts (e.g. optimization, systems) and skills (e.g. drawing and creating representations, setting up experiments) in their classrooms. Engineering education is generally not a part of K-12 education or elementary teacher education programs despite the national call for increased K-12 student performance and understanding in STEM. Few
studies have been conducted that focus specifically on preservice elementary teachers’ formative perceptions and receptivity towards engineering education. That is, not enough is known about what preservice teachers know and think about engineering.

**Purpose of the Study**

The purpose of this research study was to investigate how preservice elementary teachers’ approached engineering design, the perceptions of engineering and K-12 engineering education they possessed, and their level of receptiveness with regards to K-12 engineering education. Teacher educators will need to make informed decisions regarding when, where, and how to teach engineering content, context, and pedagogy. These decisions will depend upon the perceptions and levels of receptiveness preservice elementary teachers already possess. Preservice educators are a critical factor that will largely determine the success or failure of engineering education in K-12 schools.

**Research Questions**

1. How do preservice elementary teachers approach an engineering design task?
2. What perceptions do preservice elementary teachers possess regarding engineering and K-12 engineering education?
3. To what extent are preservice elementary teachers receptive to engineering education?

**Methodology**

To address the research questions, this study employed a qualitative design. Maykut and Morehouse (1994) stated that qualitative research seeks to investigate and respond to exploratory and descriptive questions in order to discover and deeply understand what experiences participants have had and their perceptions of those experiences. In addition,
qualitative studies can be used to add precision to a research problem (Frey & Fontana, 1993). Adding precision is beneficial due to the small number of studies that have investigated preservice elementary educators and engineering education.

The participants for this study were selected from a senior level science methods course in a teacher education program at a large Midwestern university. Forty-four preservice elementary teachers participated as a part of this course. Due to the amount of formal education the participants had completed, it was expected that they would provide the most knowledgeable responses when discussing teaching and learning. Patton (1990) states that a homogenous sample such as this can focus and simplify a study as well as facilitate group interviewing. Focus groups were the primary means of collecting data for this study.

Focus groups were selected as the primary method of collecting data for this study for several reasons. Participants in a focus group can use the varying perspectives of other participants to further understand their own thoughts and opinions (Ary, Jacobs, & Sorensen, 2010). The combination of these perspectives produces a broader range of insights. Stewart and Shamdasani (1990) state that this broader range of insights can occur as the result of one comment triggering subsequent responses from other participants. Focus groups were also selected because they provide an environment where it is more likely that participants will share their views without being fearful of having to defend themselves. Such an environment where the focus is on the group as a whole instead of individuals is more comfortable for participants and is conducive to greater open discussion (Stewart & Shamdasani, 1990).

Several factors were considered to ensure that the focus group discussions were effective and generated meaningful data. These factors included the nature of the engineering
design activity, group dynamics, moderator behavior, question planning, the environment in which the study took place, and the role of myself as the researcher.

**Study Procedures**

Data were collected using a demographic survey, online journal entries, observations, and focus group discussions. Participants were first asked to respond to an online journal prompt. This initial activity served as a primer for the focus group interviews. According to Greenbaum (1998), a focus group moderator can help participants say what they mean by having them write down their thoughts and opinions before sharing them with the focus group.

The focus groups occurred a week later. Six focus groups were conducted. Each focus group began by having participants complete a brief demographic survey. After this each focus group completed a design task where they were asked to design a parachute so that it falls as slowly as possible when dropped. No guidance was provided for the participants so that their formative understanding of design could be captured. Participants were video recorded as they completed the design task.

Once the design task was completed, the focus groups shifted to discussion. In the focus groups, participants were asked a series of questions regarding their decisions during the design activity, how the activity was related to engineering, their perception of engineering in a K-12 classroom, their feelings and attitudes towards K-12 engineering education, and their perceptions of engineers as people. These discussions were audio recorded and then transcribed for data analysis.
Data Analysis

The data collected for this study were analyzed using conventional content analysis. Conventional content analysis consists of inductively developing categories and codes after repeatedly examining the data (Hsieh & Shannon, 2005). This method is useful for studies where there is limited theory and research literature available (Hsieh & Shannon, 2005). The focus group interviews were transcribed and then analyzed along with the written journal responses. Key thoughts and concepts were identified, coded, and then sorted into categories. Codes were developed iteratively. The data were examined multiple times to identify regularities and patterns (Patton, 1980). Each subsequent examination of the data led to further refinement of the codes and their categories. This technique provided an advantage in that it allowed the data to fit tightly with the codes and provided increased sensitivity to the context of the study (Miles & Huberman, 1994). Despite this increased sensitivity to the context, this study still has its limitations.

Study Limitations

There were three primary limitations to this study. The first limitation was the result of the context in which the study occurred. This study took place at a university that is well known for its programs in engineering and technology. Due to this context, participants may have had greater exposure to engineering concepts. This increased exposure may have influenced the nature of their responses. Another limitation included an assumption made about the participants. Junior and senior preservice teachers were targeted due to the likelihood that their understanding of teaching and learning was more advanced than those beginning their formal education in teacher education, thus increasing the likelihood that participants would provide thoughtful, intelligent responses. However, junior and senior
level student do not necessarily reflect the knowledge, understanding, and perceptions of
preservice elementary teachers as a whole. The third limitation of this study is that many of
the participants in each focus group knew each other. According to Templeton (1987) this
can lead to participants endorsing each other’s views and can cause an imbalance of opinion.

Definitions of Terms

A few terms were developed specifically for this study. These terms are used
throughout the remaining chapters. Definitions for these terms are provided below:

1. Engineering Content - directly and explicitly teaching the concepts and skills that are
foundational to engineering. This includes specific concepts and skills such as
optimization, systems, the relationship between structure, behavior, and function, etc.

2. Engineering Context - a physical and instructional environment used to teach math,
science, and technology concepts. In an engineering context, engineering design
serves as the environment for the application of content in math, science, technology,
or problem solving.

3. Engineering Pedagogy - the use of specific teaching strategies that support the
acquisition of engineering content and uses engineering context to support ways of
thinking, viewing, and critiquing the world that align with engineering ways of
knowing.

4. Receptivity – the degree to which participants were willing to accept K-12
engineering education. This included willingness to share emotions along with
positive and negative dipositions.
Chapter Summary

K-12 engineering education has the potential to increase students’ understanding of how the world is designed, the reasons behind its design, and how design decisions affect everyone. The incorporation of engineering into K-12 curricula can also encourage students to critically examine the natural and designed world. However, several questions remain regarding how engineering education should be implemented in the classroom.

Current teacher education programs do not prepare elementary teachers to incorporate or teach engineering concepts and skills, and few studies have focused specifically on how preservice elementary educators perceive engineering and design. This study aimed to alleviate this problem by investigating how preservice elementary teachers’ approached engineering design, the perceptions of engineering and K-12 engineering education that they possessed, and their level of receptiveness with regards to K-12 engineering education.

A group of forty-four preservice elementary teachers were selected from a senior level science methods course to participate in the study. Participants were asked to complete a journal entry and a demographic survey and then participate in an engineering design task and focus group discussion. Focus groups were used to create an environment where participants could comfortably share their thoughts and build off of each other’s responses. Once the data were collected, conventional content analysis was used to iteratively develop a coding scheme that reflected key patterns and themes that participants expressed regarding engineering and K-12 engineering education.
CHAPTER 2. REVIEW OF LITERATURE

The development of K-12 engineering education and the knowledge of those who teach it are inextricably linked. Knowing inservice as well as preservice teachers’ background knowledge, conceptions, attitudes, and comfort level related to engineering is critical as engineering curricula, resources and materials, and professional development opportunities take shape (ASEE, 2006). However, there have been few studies that examine teachers’ conceptions of engineering and even fewer have focused on preservice elementary teachers specifically. This remains true despite the United States launching the “Educate to Innovate” campaign to improve how students participate and perform in science, technology, engineering, and mathematics, redesigned National Science Education Standards that give engineering a much more prominent role (NRC, 2011), and the addition of a technology and engineering component to the 2014 National Assessment of Educational Progress (National Center for Education Statistics, 2012). The role of engineering in K-12 schools is growing, but new policies, standards, and assessments won’t be enough to make K-12 engineering education viable. Teachers, particularly those still in preparation programs, are a critical factor that will largely determine the success or failure of engineering education in K-12 schools.

This chapter reviews the relevant literature related to K-12 engineering education. First, an overview of current K-12 engineering curricula is provided. K-12 engineering education is then discussed with regards to engineering content, engineering context, and engineering pedagogy. After this, the research about the public’s perceptions and understandings of engineering and engineering education is presented. Following the research on the public is the research that examined inservice and preservice educators. Next,
the role of teachers’ perceptions regarding teaching engineering education is discussed. The chapter concludes with a chapter summary.

**Curricular Issues in the K-12 Engineering Education Literature**

Much of the current literature on K-12 engineering education focuses on issues related to curricula, such as content integration and curriculum implementation. As Katehi, Pearson, and Feder (2009) point out, the current K-12 engineering education curriculum landscape is extremely varied. There is no widespread consensus on what such a curriculum should look like, thus making the issue a major point of discussion among scholars, curriculum developers, and educators. Despite the lack of consensus, engineering design is a common element in several curricula. A brief overview of the literature describing these curricula is discussed.

**K-12 Engineering Education Curricula**

Several of the discussions surrounding K-12 engineering education involve understanding what a K-12 engineering curriculum should contain and how it should be implemented. The National Academy of Engineering (NAE) and the National Resource Council (NRC) have contributed to this discussion by conducting an extensive analysis of thirty-four existing curricula (Katehi, Pearson, & Feder, 2009). These curricula were selected for examination because they engaged students in engineering design, explored concepts central to engineering, presented engineering as relevant to individuals and society, and possessed a sufficient amount of scale, maturity, and rigor. The researchers found that K-12 engineering education is supported by a small number of curricular and teacher professional development initiatives and that there is no widely accepted vision of the nature of K-12 engineering education (Katehi, Pearson, & Feder, 2009). In addition, existing curricula failed
to take advantage of the natural connections between engineering and the other three STEM subjects (Katehi, Pearson, & Feder, 2009).

Bagiati, Yoon, Evangelou, and Ngambeki (2010) examined online, open source engineering curricula and resources for the PreK-3 grade range and found similar results. The resources they examined included websites, conference proceedings, articles in research journals, and articles in education magazines. Bagiati et al. (2010) concluded that there is an insufficient amount of online resources available for early educators wanting to implement engineering in their classrooms. The curricula and resources that were located consisted mostly of fragmented activities and did not explicitly connect to standards in other content areas.

Locke (2009) and Rogers and Portsmore (2004) have proposed their own curricula for K-12 engineering education. Locke’s (2009) curriculum was designed to be cohesive and was to take place over the course of a student’s K-12 career, thus addressing the lack of vision and cohesiveness found by the NAE and NRC’s report (Katehi, Feder & Pearson, 2009). Rogers and Portsmore (2004) developed an engineering curriculum focused on using LEGO materials and the ROBOLAB software to engage elementary students in math, science, and design. Approaching engineering as a separate subject with its own curriculum is not the only way to implement engineering education, however.

Instead of creating entirely new curricula that would be taught as a separate class, several scholars have discussed ways to integrate engineering education into other subject areas such as math and science. Brophy, Klein, Portsmore, and Rogers (2008) discussed design-based learning for integrating engineering into existing K-12 curricula. Their argument is that design-based learning encourages the development of engineering contexts
that are accessible and interesting to learners and also provides clear links to content knowledge in math, science, and technology. English and Mousoulides (2009) also argued for the integration of engineering design in elementary and middle school mathematics curricula through the use of model-eliciting engineering-based problems. Such model-eliciting problems are said to provide students with opportunities to work in multidisciplinary contexts. English and Mousoulides (2009) also argued that using this type of problem allows multiple solutions for students with varying mathematical abilities, allows students to solve real-world engineering problems, and promotes effective communication of ideas.

Integrating engineering into secondary science and mathematics curricula has been a major point of discussion as well, receiving more attention than integration attempts at the elementary or middle school level. Integration of engineering into secondary curricula typically includes topics that are likely to be of interest to students, such as robotics (Kimmel, Carpinelli & Rockland, 2007; Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch & Kimmel, 2010). However, much of the literature on integrating engineering into secondary curricula has emphasized that technology education may be the place to start.

**Integrating Engineering Design into Technology Education Curricula**

Technology education is in a position similar to engineering education. Both are relatively new content areas in K-12 schools and definitive definitions for each are not easily found. According the International Technology and Engineering Education Association, the goal of technology education is to produce students with a strong conceptual understanding of technology and how it influences society. This includes understanding how technology is developed, designed, produced, and maintained as well as understanding how technology affects other technologies, the environment, and society (ITEEA, 2007). Technology
education is most commonly a part of secondary curricula, with some viewing it as a progression of the industrial and vocational arts, while others see it as a broad subject area incorporating ideas such as technological literacy (ITEEA, 2007, Hill, 2006).

Regardless of perspective, several scholars (Daugherty, 2005; Kelley & Kellam, 2009; Pinelli & Haynie, 2010) view technology education as a prime area for integrating the engineering design process. Hill (2006) argued that focusing on the engineering design process could provide a focus for technology education that is applicable to all students. Research conducted by Asunda and Hill (2008) described key elements of professional development sessions that aim to prepare technology education teachers to teach engineering design concepts in the context of technology education. These key elements include promoting project-based learning, getting support from administrators, establishing communities of practice, contextualizing the learning environment, using activities that are easily transferable to the classroom, and being sensitive to the thoughts, feelings, and opinions of the teachers (Asunda & Hill, 2008). Denson, Kelley, and Wicklein (2009) also conducted a descriptive study that examined how well Georgia’s secondary technology education programs integrated engineering design concepts. After collecting survey data from 214 Georgia teachers, they found that 76% of the technology education teachers claimed they were already teaching engineering design in their classrooms; however, 63% said they were unaware of any engineering-based curriculum. Denson et al. (2009) concluded that although engineering design was viewed positively, a lack of training, resources, and awareness prevented these teachers from providing effective instruction on engineering design.
Extending their research with Denson, Kelley and Wicklein (2009) went on to collect more data on the challenges secondary technology education teachers encounter when implementing engineering design. They found that teachers had a difficult time identifying appropriate concepts in math and science that could be integrated into engineering design. While scholars continue to contemplate what a K-12 engineering curriculum should look like or how technology education might serve as the context for engineering education, design has emerged as one of the few constants. The design process is a critical component of K-12 engineering education and understanding what is meant by design is crucial for teachers as they attempt to integrate engineering into their classrooms. Engineering design can be approached using engineering content, engineering context, and engineering pedagogy.

**Approaches to Engineering Design**

Scholars agree that engineering and consequently engineering education center around the engineering design process (Katehi, Feder & Pearson, 2009; Asunda & Hill, 2008; Linnell, 2007; Denson, Kelley & Wicklein, 2009; Hill, 2006; Locke, 2009; Smith & Burghardt, 2007). While there is general agreement that the engineering design process is the key element to engineering education, there are many views on what is included in the process and the knowledge that is required to participate in engineering design. The International Technology and Engineering Education Association (ITEEA, 2007) and Eide, Jenison, Mashaw and Northrup (2001) both provided step-by-step processes for engineering design. Others such as Katehi, Feder and Pearson (2009) argued that there is no step-by-step process or formula for engineering design, stating that the process is best understood through the identification of key characteristics. Regardless of how engineering design is viewed, scholars agree that it is a systematic and iterative process that involves identifying a problem,
generating ideas, specifying constraints, evaluating solutions, and testing models (Katehi, Feder & Pearson, 2009; Silk & Schunn, 2008; ITEEA, 2007; Eide et al., 2001). Determining whether or not the engineering design process is step-by-step or variable is only part of the complexity related to K-12 engineering education.

Upon examination of the literature and existing curricula, K-12 engineering education can be approached in three ways. These three approaches can each be used as ways to address how to implement engineering education. Each may be used individually or they may be used in combination. The first approach is content. Engineering content includes directly teaching the concepts and skills that are foundational to engineering. The second approach is engineering context. This involves using engineering as a context for teaching subjects such as science and math. Engineering content may still be present, but it is secondary to the math or science content being taught. The final approach is engineering pedagogy. An engineering pedagogy involves the use of specific teaching strategies that support the acquisition of engineering content and uses engineering context to support ways of thinking that are consistent with engineering epistemology. The following three sections further elaborate on each approach.

**Engineering Content**

A commonly advocated approach to K-12 engineering education is to teach engineering content, including both concepts and skills, to K-12 students. Several curricula currently exist that utilize this approach. Examples of such curricula include Project Lead the Way, the Infinity Project, and Engineering the Future. These curricula focus on domain-specific knowledge. Project Lead the Way teaches students about topics such as robotics, computer-integrated manufacturing, and aerospace engineering (PLTW, 2012). The Infinity
Project, developed by Southern Methodist University, includes a unit on robotics, sound engineering, and biomedical engineering (The Infinity Project, 2012). The Boston Museum of Science’s Engineering the Future curriculum includes units on electronics, alternative energies, and rocketry (Engineering the Future, 2012). Students learn about specific engineering specializations (e.g. aerospace, sound, biomedical, etc.) They also are taught concepts that reside specifically within the domain of engineering. For example, Project Lead the Way instructs students on statics and kinematics. The goal of curricula such as these is to explicitly teach engineering content.

What counts as engineering content in K-12 schools is still being debated. To examine this issue, many scholars have focused on non-domain-specific concepts in engineering instead of the domain-specific concepts found in many of the current curricula. Silk and Schunn (2008) addressed this issue by providing concepts that are not domain-specific. Instead, these concepts are “shared across most areas of engineering” and “representative of the essential knowledge that distinguishes engineering from other disciplines and the knowledge that is needed for students to be able to understand and engage competently in the practice of engineering design” (Silk & Schunn, 2008, p. 3). These core concepts focus on two areas: systems and optimization, and cover items such as the relationship between structure, behavior, and function and the need to consider multiple variables during the design process. This is a broader perspective than that of curricula such as Project Lead the Way. The concepts described by Silk and Schunn (2008) apply to design in engineering, but also apply to design in general.

Petrosino, Svihla, and Brophy (2008) state that in addition to systems and optimization, engineering content also includes the skills necessary to participate in
Engineering design is the approach engineers use to determine the best way to construct a device or process that serves a specific purpose (Katehi, Pearson & Feder, 2009). Engineering design skills include: defining the problem, specifying requirements, decomposing systems, generating solutions, drawing and creating representations, and experimenting and testing (Petrosino et al., 2008). According to Petrosino et al. (2008), these skills are important because they focus on design and redesign, the essential engineering processes.

Other scholars claim that constraints, optimization, and predictive analysis (COPA) are the three essential engineering concepts (Merrill, Custer, Daugherty, Westrick & Zeng, 2008). Predictive analysis involves using math and science to make informed decisions before constructing a model or prototype. While predictive analysis is seen as crucial for engineering, it is often left out of the design process (Gattie & Wicklein, 2007; Katehi, Feder & Pearson, 2009).

According to Gattie and Wicklein (2007), mathematical analysis is a fundamental distinction between an engineering design process and a technology education, or technological design process (Table 1). While most of the curricula that Katehi et al. (2009) examined claimed to use the engineering design process, they found that several actually use a design process that is more technological in nature due to a lack of mathematical analysis.

**Engineering Context**

Engineering context is another approach for implementing K-12 engineering education curricula. Using engineering as a context involves teaching content that is embedded in an engineering design problem with a clear purpose and requires the use of the
systematic engineering design process. In an engineering context, engineering content is not necessarily taught explicitly. Instead, engineering design serves as the environment for the application of content and concepts most typically in science, math, technology or problem solving. Such a context could be used to teach basic arithmetic, algebra, water conservation, electrical circuits, and many other concepts.

An effective engineering design context allows learners to be generative, reflective, and adaptive in their thinking as they plan, make, and evaluate devices, systems, or processes (Brophy et al., 2008). The engineering design problem that is used should be tied to the real world, embedded in the iterative and systematic engineering design process, complex enough to allow for multiple solution paths, and require teamwork (Jonassen, 2000). Using an engineering context requires the establishment of a classroom learning environment that has
time, resources, and support to be conducive to such a context. An engineering design problem takes more time to solve than a typical textbook problem, may require materials that are not commonly found in the classroom (e.g. batteries, wires, nuts, screws, etc.) and requires a teacher that understands the engineering design process and how to support students’ learning in an engineering context.

Engineering context is not an instructional environment necessarily limited to teaching science, mathematics, and technology. Other subjects, such as social studies and language arts, could be taught using an engineering context (Brophy et al., 2008). For example, a teacher could approach a lesson in language arts from a technical communications perspective, focusing on how the design of the communication impacts the transmission of key ideas such as how the parts within a system work together. Including a technical writing or communication component in language arts would provide students with an understanding of how engineers and other technical professions communicate. Social studies includes content on ancient and modern structures and technologies that could be connected easily to engineering. For example, a teacher could discuss the design variables and constraints that the Egyptians would have needed to consider while constructing the pyramids. Using an engineering context in social studies also provides ample opportunities to discuss the societal impact of engineering.

Several curricula exist that attempt to use engineering as a context for learning. However, engineering as a context for learning is dependent upon the engineering design process. Because there is some variability in how the engineering design process is defined, engineering contexts can vary as well. For elementary students a design context may be framed using a “planning, making, and evaluating” process (Fleer, 2000). Engineering
contexts for secondary students can expand upon this process by formally identifying and defining the problem, identifying constraints, creating prototypes, and communicating results (ITEA, 2000). As with any context in K-12 schools, an engineering context is designed so that it is developmentally appropriate for students.

Engineering curricula in the elementary grades appear to use engineering more as a context than a content area. For example, the Engineering is Elementary curriculum teaches various science topics (e.g. the water cycle, wind and weather, insects, etc.) through the context of design activities (EiE, 2012). The learning objectives of this curriculum are grounded in science but are achieved through the context of engineering design. Although secondary curricula favor the engineering content approach, they also attempt to utilize engineering design contexts. Students involved in Project Lead the Way or Project Infinity participate in design activities. While content and context are closely linked, an engineering context is not always necessary to teach engineering content. For example, the domain-specific knowledge (e.g. statics) in Project Lead the Way is not necessarily taught using an engineering context. In secondary environments, design can shift from being solely a context to becoming part of the content students learn.

While curricula such as Project Lead the Way, Project Infinity, and Engineering is Elementary are impacting schools in the U.S., they still only reach a small percentage of the 55 million students in K-12 schools (National Center for Education Statistics, 2011). In a typical K-12 classroom science, technology and mathematics are typically taught in isolation from each other (Katehi, Pearson & Feder, 2009). While science and math typically have their own dedicated blocks of time, engineering and technology are rarely taught despite the ongoing national attention STEM education has received. Katehi, Pearson and Feder (2009)
state that the teaching of STEM subjects must move away from the current “silo” structure and be replaced by an interconnected whole. According to these researchers, the context of engineering may serve as a way to do this. Yet, context can be thought of simply as a part of much broader pedagogy.

**Engineering Pedagogy**

The pedagogy of engineering education encompasses both the content and context approaches but is much more than a mere combination of these two perspectives. As with the previous two approaches, much uncertainty exists regarding what an engineering pedagogy would look like. According to Shulman (1987), pedagogy involves the teacher’s ability to “transform understanding, performance skills, or desired attitudes into pedagogical representations and actions. These are ways of talking, showing, enacting, or otherwise representing ideas so that the unknowing can know, those without understanding can comprehend and discern, and the unskilled can become adept” (Shulman, 1987, p. 7). An engineering pedagogy includes the methods and practices teachers use to engage students in the nature and habits of mind of engineering. This requires a teacher to consider several items, such as:

- Deciding how to have students create a design based upon the structure/content of a lesson (e.g. build physical models/prototypes or use computer simulations).
- Being able to identify developmentally appropriate, content-specific concepts within a design and making those concepts apparent to the students and relevant to the lesson.
- Understanding how the variables involved in a design are interrelated and how to make this apparent to students.
• Being able to identify and communicate the social aspects of design, such as how a
design impacts how people travel, communicate, or create.

• Using a systematic design approach instead of trial and error.

Moreover, engineering pedagogy can also promote engineering as a way of thinking
or a way to view and critique the world (Katehi, Pearson & Feder, 2009). For example,
engineering can be used to promote a “world view in which possibilities and opportunities
can be found in every challenge and an understanding that every technology can be
improved” (Katehi, Pearson & Feder, 2009, p. 152). Such pedagogy can also be used to
critically examine our society and ask questions regarding the ethics of engineering, who can
be an engineer, and the social implications of the devices, systems, and processes engineers
produce. These questions align with the critical pedagogy of Giroux (2001), who believes in
providing students with “the critical capacity to challenge and transform the existing social
and political norms, rather than simply adapt to them” (p. 47). This pedagogy recognizes that
women and non-whites are commonly viewed differently in the engineering profession, that
engineering can be used for good and ill, and that engineering doesn’t always benefit all parts
of society equally.

The literature provides little guidance on specific principles of engineering pedagogy.
According to Silk and Schunn (2008), engineering pedagogy requires: a sufficient amount of
instructional time for design activities, that the design process be purposeful and iterative,
that items should be sequenced from easier to more difficult, and that appropriate tools be
used to highlight and represent important ideas. While it is important to recognize these
guidelines, they do not address all aspects of engineering pedagogy as a whole. Silk and
Schunn’s (2008) guidelines focus on the strategies and management portion of an
engineering pedagogy, but fail to provide detailed information related to the pedagogical representations of ideas discussed by Shulman (1987) and the critical pedagogy of Giroux (2001). Engineering pedagogy needs to be inclusive of these components to be legitimate. This inclusion will also ensure its effectiveness and maximize its ability to transform students.

While content, context, and pedagogy have been neatly separated here, such neat separation is not mirrored in reality. The pedagogy used depends heavily on the way the learning context is structured as well as the nature of the content being taught. Content can also influence how the context is structured. Shulman (1986) emphasized this point with his discussion of teacher pedagogical content knowledge (PCK). By PCK he meant understanding “the ways of representing and formulating the subject that make it comprehensible to others.” (Shulman, 1986, p. 9) An example of this in engineering education includes deciding whether students should design physical artifacts or design artifacts using simulations and understanding the affordances and constraints of each approach. This includes understanding what is easy or difficult about content topics and what common misconceptions students may possess. Understanding that content, context, and pedagogy are inextricably linked has important implications for engineering education.

Summary of Engineering Curricula and Design

Current discussions on K-12 engineering education frequently center on curricula. Katehi, Pearson, and Feder (2009) and Bagiati, Yoon, Evangelou, and Ngambeki (2010) examined several existing K-12 engineering curricula and found that the curricula are extremely varied, sharing no common vision. Scholars such as Locke (2009) and Rogers and Portsmore (2004) have proposed constructing new K-12 engineering education curricula that
occur throughout a student’s K-12 career in an attempt to provide cohesiveness. Other scholars have argued that engineering should be integrated into existing math, science, and technology curricula (Brophy, Klein, Portsmore, & Rogers, 2008; English & Mousoulides, 2009; Kimmel, Carpinelli, & Rockland, 2007; Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, & Kimmel, 2010). The nascent curricula in technology education have also been viewed as a way to include engineering education in K-12 schools (Asunda & Hill, 2008; Denson, Kelley, & Wicklein, 2009; Daugherty, 2005; Hill, 2006; Kelley & Kellam, 2009; Kelley & Wicklein, 2009; Pinelli & Haynie, 2010).

Despite the variation that exists in current K-12 engineering education curricula, engineering design was found to be a common component (Asunda & Hill, 2008; Denson, Kelley & Wicklein, 2009; Hill, 2006; Katehi, Feder & Pearson, 2009; Linnell, 2007; Locke, 2009; Smith & Burghardt, 2007). Engineering design can be approached using engineering content, engineering context, and engineering pedagogy. Engineering content includes directly teaching the concepts and skills that are foundational to engineering. An engineering context provides both a physical and instructional environment to teach math, science, and technology concepts. Finally, an engineering pedagogy involves the use of specific teaching strategies that support the acquisition of engineering content and uses engineering context to support ways of thinking, viewing, and critiquing the world that align with engineering ways of knowing.

**Perceptions of Engineering and K-12 Engineering Education**

The research literature associated with perceptions of engineering and K-12 engineering education is far from complete. Only a handful of studies have examined how the public and educators perceive engineering and engineering education. The lack of
research may be a reflection of the uncertainty surrounding concepts and skills in engineering design. Both qualitative and quantitative research methods have been used but the results of these studies are not always consistent with each other. The methodological decisions made by researchers also have influenced the nature of the information gained from these studies. This section examines research on how the general public, inservice, and preservice teachers perceive engineering. This section concludes with a discussion on the role of perception in educators’ readiness for engineering education.

**Public Perceptions of Engineering**

There is an increasing concern in the United States that not enough people are pursuing careers in technical fields such as engineering. Due to this concern, organizations such as the American Association of Engineering Societies (AAES) and the National Academy of Engineering (NAE) have made efforts to understand and shape the public’s perceptions of engineering. The AAES began examining how the public views engineers and engineering in 1998 by hiring a marketing agency to survey 1,000 randomly selected adults in the U.S (Davis & Gibbin, 2002).

The NAE expanded upon this work to further raise the public’s awareness of engineering in 2008 when it developed and tested several new messaging themes regarding engineering. These messages targeted students ranging from nine to nineteen years old along with parents. The objectives of the project were to identify messages that would improve the public’s understanding of engineering, test these messages with various target audiences, and then share the results with the engineering community (NAE, 2008). The development and testing of these messages were done using both qualitative and quantitative methods. Qualitative methods were used first and included twelve in-depth telephone interviews, five
focus groups, and four “youth triads.” Four of the five focus groups contained participants 12 to 15 and 16 to 19 years of age. The fifth focus group consisted of parents who had children 9 to 19 years of age. Finally, four same-sex youth triads were conducted with children ranging from 9 to 11 years of age. A total of 28 teens, 12 pre-teens, and 10 adults participated in the focus groups and triads (NAE, 2008). The participants were recruited using external marketing and strategy groups.

After the qualitative data was collected, a quantitative online survey was administered in two phases. The first phase surveyed 666 adults and 568 teens, ages 14 to 17. Only 12% of the adults and 20% of the teens were non-white. Due to their underrepresentation in engineering, African Americans and Hispanics were a key target audience for the researchers, so a second phase was conducted that included 605 African American adults, 608 Hispanic adults, 535 African American teens and 566 Hispanic teens. As with the qualitative research, all of these participants were recruited using marketing and strategy groups external to the NAE (NAE, 2008).

Despite being a decade apart, the survey commissioned by the AASE (1998) and the research conducted by the NAE (2008) had similar findings. Participants in both studies felt they were uninformed with regards to engineering. Over 60% of the respondents in the AASE survey (Davis & Gibbin, 2002) replied that they were “not very” or “not at all” informed and the participants in the NAE’s (2008) focus groups and youth triads also indicated that they had a very limited understanding of what engineers do. Both studies indicated that the public strongly associates engineering with building or constructing machinery, failing to acknowledge engineering’s contributions in other domains such as medicine or energy production or the role that designing and planning serves in engineering
The AASE survey also showed that respondents often confused engineers with scientists and technicians. Despite their lack of understanding, parents in both studies indicated that they would be pleased if their children chose a career in engineering (Davis & Gibbin, 2002; NAE, 2008). When students were asked about engineering as a career choice boys were almost twice as likely as girls to consider engineering a good choice regardless of ethnicity. Both male teens and adults across all groups in the NAE’s 2008 survey were more confident with their knowledge of engineering than female teens and adults (NAE, 2008).

In general, the engineering profession was viewed positively in the studies initiated by the AASE and the NAE. However, when asked about engineers as people, respondents described engineers as being myopic, less concerned about societal issues, and isolating themselves from society (Davis & Gibbin, 2002; NAE, 2008). Students in the NAE’s (2008) study further elaborated upon this idea by describing engineers as sedentary and working primarily at a computer. The adults in the NAE’s qualitative interviews believed engineers are often stereotyped as being intelligent but “nerdy.” They also felt engineering lacks a “public face” or personality, that engineering is taken for granted, and that the lack of diversity in engineering is a concern. The results of the NAE’s survey also indicated that both adults and teens found a high level of skill in math and science to be the distinguishing characteristic of engineers. Despite the stereotype mentioned during the qualitative interviews, less than 15% of adults or teens felt engineers were boring or nerdy. However, teens in the first, predominantly white, survey group were three times more likely as adults to think of engineering as boring and twice as likely to view engineers as nerdy. A larger number of teens than adults believed engineers to be hard workers (NAE, 2008).
The AASE’s (Davis & Gibbin, 2002), survey also asked respondents about the media’s coverage of topics related to engineering. More than 69% of the respondents stated that the media does a fair or poor job of covering engineering discoveries. The respondents believed this lack of coverage was due to Americans not being able to understand and not being interested. The AASE also found that respondents with a higher level of education were more likely to have a better understanding of engineering (Davis & Gibbin, 2002).

Realizing that education is an important component of improving the public’s understanding of engineering, the NAE built upon the information collected by the AASE and surveyed 628 engineering outreach organizations to determine their scope, nature, objectives, and effectiveness. These organizations including engineering societies, universities, museums, design firms, national laboratories, etc. and primarily targeted K-12 students. A total of 224 organizations responded. After analyzing the responses, the NAE found that no single program, based on objective measures, could be cited as particularly effective even though the total expenditures for all programs was estimated to be nearly $400 million (Davis & Gibbin, 2002).

The research literature indicated that, as a profession, the general public views engineering positively despite not fully understanding what engineering is. Respondents commonly associated engineering with construction and machinery without considering the roles of designing and planning. As people, engineers were perceived as being skilled in math and science. Respondents also depicted engineers as socially inept or nerdy. Despite the difficulties organizations have encountered when attempting to reach the general public and K-12 students and the increasing role of engineering in STEM education discussions, researchers in education have conducted few studies with teachers.
Inservice Teachers’ Perceptions of Engineering

As with studies examining the public’s understanding of engineering, there are few studies that have explicitly examined what K-12 inservice teachers know and understand about engineering. A study conducted by Lambert, Diefes-Dux, Beck, Duncan, Oware, and Nemeth (2007) sought to understand how elementary teachers describe engineering and what engineers do and how participation in a week-long academy on engineering influenced teachers’ descriptions. Two week-long summer academies were held. Thirty-three local teachers volunteered to participate in the first academy. Fifty-three teachers from across the U.S. applied to the second academy and thirty were accepted. Teachers were selected based upon the strength of their teaching philosophy, skills, attitudes, and an expression of interest in using engineering content in their classrooms.

Data were collected using qualitative methods in the form of two questions, asking participants what they thought engineering was and what they thought engineers do. Both questions were administered before and after the academies took place. The researchers found that the teachers commonly believed engineers design, build, construct, make, or improve products. The idea that problem solving is involved was also present but to a lesser degree. Only 12% of the teachers in the local academy and 43% of the teachers in the national academy discussed applying math, science, or technology in engineering. Few of the teachers mentioned that engineering impacts our daily lives, requires teamwork and communication, and requires a global perspective. The teachers participating in this study also did not discuss creativity and constraints, key concepts in engineering.

After coding the data qualitatively, Lambert et al. (2007) quantitatively analyzed the data by considering participants’ responses as a difference of two proportions. The only
significant difference, with difference being measured as the percent of teachers with at least one response coded in a main category, between the local and national teachers was that the national teachers discussed the application of math, science, and technology to a greater extent. When pre-to-post responses were compared, there were significant differences with respects to participants mentioning teamwork, engineers serving clients, and engineering as a process (Lambert et al., 2007). The researchers did not examine how knowledge gained at the one-week professional development academy impacted teaching strategies over the long term.

Similarly, the American Society for Engineering Education (2006) asked inservice teachers “What is engineering?” The researchers behind this study intended to collect information on teachers’ preconceptions of engineering and technology as a way to inform professional development and curricular decisions. The participants in this study included 106 teachers, most of them residing in Massachusetts and 86% teaching in an elementary school. Each participant completed a survey that gathered information on years of teaching experience, the amount of time they spend in science instruction, and their experiences with science, technology, and engineering. The teachers had little to no experience teaching engineering to their students, with 63% reporting they did nothing related to engineering during the previous school year. A small portion (10%) reported that they taught more than 20 engineering lessons during the prior year; many of these participants were science specialists (ASEE, 2006).

After this, the teachers were also asked to complete additional instruments. The additional instruments required participants to identify images that are associated with the type of work engineers do and to respond to writing prompts. Seventy-five teachers
responded to the writing prompts. The writing prompts had participants complete the phrase “An engineer is a person who…” or answer the question “What is engineering?” (ASEE, 2006).

The analysis of the image identification instrument indicated that 80% of the teachers believed that engineers actually construct objects, such as buildings or bridges. However, the researchers failed to state how many teachers completed the image identification instrument. Teachers were likely to believe that engineers are people who construct and repair technology. Because of their broad interpretation of design, between 25-35% of the teachers believed engineers do things such as arrange flowers, sell food, or make pizza. These teachers were also likely to believe that engineers are people who use any type of technology to do their work. This led them to conclude that nearly everyone could be considered an engineer.

The 75 responses to the writing prompt “An engineer is a person who…” showed that 65% of the teachers believed engineers are people who design or improve technologies, generate new ideas and plans, and work towards goals. Another common response mentioned by 47% of the teachers referred to problem solving, imagination, science, math, materials, teamwork, how things work, and the use of tools. Several teachers (44%) held the misconception that engineers actually construct new technologies or structures. The researchers stated that these results indicate that teachers often view engineers as construction workers or technicians that work primarily with machines (ASEE, 2006).

The findings from the ASEE (2006) study indicating that elementary teachers view engineering as synonymous with construction aligns with the results found by Lambert et al. (2007) and the NAE (2008). The pretests in the Lambert et al. (2007) study also showed that
elementary teachers have difficulty differentiating engineering from construction. The NAE (2008) study indicated that the public also struggles with this idea.

The American Society of Engineering Education conducted a study in 2005 that examined inservice teachers’ attitudes about engineering (ASEE, 2005). Using a survey, the researchers sought to understand the views K-12 teachers held about engineering, engineers, and engineering education to improve the ASEE’s outreach efforts. Due to a loss of documentation, the total number of respondents is unknown; thus, the findings from this research should be taken lightly (ASEE, 2005). A brief summary of the results from the ASEE is reported here because they have suggestions for how inservice teachers perceive engineering.

According to the ASEE, the teachers who responded to the survey had been teaching on average for approximately fifteen years. A majority of the teachers taught science, math, or technology at the high school level, with 76.2% teaching in public schools. Fifty-six percent of the teachers responded saying that only “some” of their students could succeed as engineers. While the respondents felt engineering was fairly accessible to everyone despite race, they believed a strong understanding of math and science is needed. The idea of using engineering as a way to teach other subjects, such as history and language arts, was looked upon favorably (more agreed than strongly agreed). When asked if anyone could become an engineer through determination and education, the respondents were split, with 33.2% disagreeing and 32.0% agreeing. However, when asked how many of their students could succeed as engineers, 56.3% said “some” while 12.8% said “few.” These teachers felt confident in their knowledge of engineering, with 68.0% agreeing or strongly agreeing to the
statement “I know enough about engineering to help students decide if they should be engineers.” (ASEE, 2005)

Of the teachers who participated in this survey, 70.3% strongly agreed that engineers have to be good at math and science, 51.7% strongly agreed that engineering could be used to teach science, 66.9% strongly agreed that engineering has a large impact on daily life, 37.7% strongly agreed that a basic understanding of engineering is important, and 39.1% strongly agreed that understanding more about engineering could help them become a better teacher. However, without knowing the exact number of respondents it is not possible to draw strong conclusions from this study (ASEE, 2005).

Yasar, Baker, Robinson-Kurpius, Krause and Roberts (2006) developed a survey to assess how K-12 science teachers perceive and understand design, engineering and technology (DET). The purpose of the study was to offer recommendations for integrating DET concepts into teacher education and K-12 curricula. Any teacher teaching science at any grade level in Arizona was invited to complete the survey. This survey was administered online and via mail. While much research has focused primarily on understanding how people perceive and define engineering (Davis & Gibbin, 2002, 2008; Lambert et al., 2007; ASEE, 2005, 2006), this survey provided information on barriers and affordances to implementing DET in K-12 classrooms, levels of familiarity and comfort with DET, stereotypes, gender preferences for DET, impact of teaching experience, grade level differences and preferred methods of obtaining DET knowledge. Ninety-eight teachers responded, with an average of 10.5 years of teaching experience. Of the 98 respondents, 13 were elementary teachers, 42 were middle school teachers, and 35 were secondary teachers. Fifty-six were female and 42 were male (Yasar et al., 2006).
Overall, the teachers believed DET to be important and that it should be incorporated into the curriculum. However, there was a significant difference between male and female teachers regarding the importance of DET. A larger number of female teachers felt that DET was important to teach when compared to their male counterparts. The results of the survey also indicated that female teachers were more familiar than male teachers with the characteristics of a typical engineer. Engineers were viewed as people who have good math and science skills, like to repair things and get paid a large salary.

Regardless of gender, the participants’ were confident of their views of engineering, but their confidence and familiarity with DET concepts were weak. Participants attributed their lack of confidence and familiarity to a lack of content knowledge, lack of preservice education, and lack of time. The teachers also believed that many people hold stereotypical views of engineers, such as being male or non-minority. However, due to the way the survey was phrased, it is not possible to determine if the teachers themselves held these stereotypes. Participants also indicated that they viewed engineers as lacking writing, verbal and people skills. When looking at stereotypes and the social skills of engineers, the teachers in this study resemble the participants in the studies conducted by the AASE (Davis & Gibbin, 2002) and the NAE (2008). Participants in each of these studies viewed engineers as people with good math and science skills that isolate themselves from society and possess poor communication skills (Davis & Gibbin, 2002; NAE, 2008; Yasar et al., 2006).

With regards to grade level, DET was most important to middle school teachers, followed by high school teachers. Elementary teachers who participated were the least interested in DET concepts and did not view them as a high priority (Yasar et al., 2006). Teachers with the least amount of teaching experience believed that their preservice teacher
education programs prepared them to teach DET concepts. Yasar et al. (2006) believed this finding could be the result of teacher education programs emphasizing national science and technology standards and teaching with technology. While novice teachers felt most prepared, Yasar et al. (2006) noted that none of the teachers in the study indicated strong familiarity with DET concepts. As teaching experience increased, teachers became less interested in learning how to integrate DET concepts into their classrooms. The less experienced teachers identified time as a barrier to using DET concepts while more experienced teachers responded that time was not an issue.

Baker, Yasar-Purzer, Kurpius, Krause, and Roberts (2007) conducted qualitative case studies that investigated the effects of a graduate level course designed to teach design, engineering, and technology (DET) concepts to K-12 educators. Three graduate students in a science education master’s program participated in the study. The first graduate student was an elementary teacher who did not have any formal background in science but instead had acquired a sufficient understanding of science on her own (Baker et al., 2007). The second graduate student taught at a science center where she developed workshops and activities for children. The third graduate student was a high school chemistry teacher and chair of her science department. Data were collected using open-ended pre/post questions, reflection papers, course artifacts, and interviews. The open-ended pre-post questions asked the three graduate students to describe the design process, define “tinkering,” define “technical expertise,” describe how science and engineering are related, state how much time should be devoted to DET concepts in K-12 curricula and why, and describe how they would modify existing curricula to include DET concepts.
After collecting the data, Baker et al. (2007) organized and reduced the data into categories so that patterns could be identified. All text referencing teaching was extracted and then coded. Four themes emerged: changes in knowledge, reflections in practice, changes in practice, and intentions to change practice. The first theme indicated that the three participants gained an understanding of the design process and its language. The graduate students expressed that the design process is iterative and that science and technology are reciprocal. When reflecting on their practice, the teachers stated that using a systematic design process approach was an improvement over simply having students make something without talking about DET concepts. The graduate students also expressed that providing an everyday context for DET was difficult. The course led to changes in practice for the teachers, including a focus on the design process, constraints, and requirements. The participants also redesigned several of their lessons to allow for multiple solutions and to highlight the relationship between design, science, and technology. After completing the course, the teachers stated that they intended to explicitly teach the iterative design process, teach using model building, develop workshops on properties of materials, focus on collaboration and communication among students, and help other teachers incorporate DET concepts into their classrooms (Baker et al., 2007). While there were few studies that examined the understandings of engineering that inservice educators possessed, even fewer have been conducted with preservice educators.

**Preservice Teachers’ Perceptions of Engineering**

There is a paucity of research with regards to preservice teachers and engineering education. Very few studies have been conducted that focus specifically on examining preservice teachers perceptions of engineering.
Hudson, English, and Dawes (2009), conducted a quantitative study of seventeen Australian preservice teachers’ potential for implementing engineering education in a middle school setting. While participating in this study, the preservice teachers were enrolled in a science education course. Part of this course was a weekly, two-hour workshop that provided the preservice teachers with hands-on experiences. Hudson et al. (2009) used two of these workshop sessions to scaffold participants towards implementing engineering activities. This scaffolding was accomplished by providing the participants with the scientific and mathematical concepts behind two engineering activities: building a bridge and floating a boat. Responses were collected before and after these workshops using a 25-item survey that consisted of four constructs: personal professional attributes (e.g. self efficacy, self confidence, attitudes toward subject matter, etc.), student motivation, pedagogical knowledge, and fused curricula (i.e. fusion of science and mathematics curricula).

The results of the study showed that after participating in the two workshops, the preservice teachers “perceptions of enthusiastically facilitating engineering lessons” increased from 60% to 88% \((p = 0.08)\) and their confidence for teaching engineering increased from 18% to 77% \((p = 0.01)\) (Hudson et al., 2009). Eighty-eight percent of the participants \((N=17)\) believed they could motivate students to engage in engineering activities. When the pedagogical knowledge construct was examined, the posttest showed that the participants’ perceptions had improved regarding the selection of appropriate resources and equipment \((41\% \text{ to } 94\%, p < 0.01)\), guiding students into independent studies of engineering \((41\% \text{ to } 88\%, p < 0.01)\), and working with students to solve engineering-based problems \((47\% \text{ to } 88\%, p < 0.01)\). Participants’ understanding of using effective questioning strategies during engineering lessons did not increase due to the already high understanding they
The researchers believe this indicates that the participants recognized that pedagogical techniques such as questioning strategies are transferable from subject to subject. Regarding the construct of fused curricula, the researchers stated that the percentages doubled or more than doubled on items related to applying mathematics and using technology for understanding engineering (Hudson et al., 2009).

In contrast to the quantitative study conducted by Hudson et al. (2009), Gallager (2004) conducted a qualitative case study using a cohort of 22 female preservice teachers enrolled in a course that featured engineering principles. Nineteen of the participants were classified as elementary education majors, two were classified as early childhood education majors, and one participant was enrolled in secondary education. The engineering principles were presented primarily through computer programming and Lego robotics kits. The goals of this study were to: determine how preservice teachers’ perceptions develop while participating in the course; how constructivist learning effects preservice teachers’ perceptions of science and technology; how preservice teachers describe their experience with engineering-based projects; and how preservice teachers describe the implementation of what they learned from the course. Gallager (2004) collected data using classroom observations, field observations, reflective journals, online postings, project artifacts, and personal interviews.

At the beginning of the study, Gallager (2004) distributed a questionnaire to participants that asked “What is engineering?”, “What does an engineer do?” and “Do you remember learning about engineering in school? If so, what memories do you have?”. Several defined engineering by listing fields within engineering such as mechanical,
computer, etc. Some participants defined engineering using terms such as building, creating, designing and inventing. When asked to further explain these terms, the preservice teachers provided limited detail as to what they meant. The preservice teachers also had difficulty verbalizing why engineering concepts are important to teach in K-12 schools and many did not initially see the relevance of K-12 engineering education.

As Gallagher’s study progressed, the preservice teachers began to recognize that engineering could be used as a context for teaching math and science. The participants described their experiences in the course as fun, creative, engaging and frustrating. Working together in pairs or teams was the preferred method of completing the activities in the course. After the course was completed, Gallager (2004) examined individual students to determine their thoughts on implementation. Only one of the preservice teachers was examined closely at this stage; this student showed a capacity to apply what she had learned from the course to other curricular areas such as reading. The participants in Gallaher’s (2004) study chose to enroll in her course, suggesting they had an interest in science or technology teaching. This study provided a good foundation for understanding the perceptions that preservice educators possess regarding engineering.

**Role of Perceptions in Educators’ Readiness for Engineering Education**

Several research studies on engineering education (Baker et al., 2007; Lambert et al., 2007; Gallager, 2004; Hudson et al., 2009) were conducted in an attempt to understand how some treatment (e.g. workshop, academy, new course) influenced the understanding, perceptions, and instructional actions of educators. These studies focused primarily on how the educators were different due to their participation. However, the perceptions that the participants possessed prior to their participation are important. In the studies conducted by
Baker et al. (2007), Lambert et al. (2007), Gallager (2004), and Hudson et al. (2009) it is unclear whether the pretest information collected was used to develop their workshops, academies, and courses or if the pretest information was collected and then used solely as a comparison for the posttest data. The researchers do not elaborate on how decisions were made with regards to the development of their instruction. Understanding the formative perceptions that teachers possess can provide guidance in how to develop workshops, academies, and courses such as those described by Baker et al. (2007), Lambert et al. (2007), Gallager (2004), and Hudson et al., (2009).

In research on teachers’ thinking, perception has been used in conjunction or interchangeably with several other terms such as beliefs, values, attitudes, opinions, ideologies, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, personal theories, and perspectives (Pajares, 1992). In this study perception is defined as a component of affective learning and a way of understanding, regarding, or interpreting a particular concept. With learning theories that view thinking and learning as information processing, perception and the affective learning domain in which it resides have often been ignored or marginalized (Picard, Papert, Bender, Blumberg, Breazeal, Cavallo, Machover, Resnick, Roy, and Strohecker, 2004). However, perception has an important role in teaching and learning.

According to Picard et al. (2004), affective components of learning such as perception, motivation, emotion, interest, and attention are “complexly intertwined with cognition” and help guide rational behavior, memory retrieval, decision-making, and creativity. The intertwined nature of the cognitive and affective learning domains forms a relationship between a learner and the process and content of learning (Picard et al., 2004).
Nespor (1987) made similar claims when he suggested that teachers’ use their perceptions to identify relevant goals, to interpret and simplify the classroom environment, and to adjust themselves to particular problem situations. The influence of perception is broad, impacting how a teacher views learners and learning, teaching, subject matter, learning to teach, and themselves as a teacher (Calderhead, 1996). While there is a relationship between the affective and cognitive learning domains, other relationships exist among the components of the affective domain.

Perception is one of several components in the affective learning domain. Other components include motivation, emotion, interest, and attention (Picard et al., 2004). The perceptions that teachers hold interact not only with their cognitive abilities, but also the other components of the affective learning domain. Emotion in particular has a strong relationship with perception. According to Minsky (2003), a shift in emotional states results in shifting to a different way of thinking. It is possible for two individuals to objectively understand a concept in a similar way but subjectively perceive the concept differently based upon how the concept makes them feel. An analogy to this includes two people learning how to drive. Both people know what a car is and what it does. However, one of these novice drivers has a car accident as he or she is learning to drive. While both of these people share an objective understanding of a car, their perceptions of cars would differ. The driver who was involved in the accident may view cars as more dangerous, have less confidence in their driving skills, or may be fearful of continuing to drive when compared to the driver who was not in an accident. Perception strongly influences how people understand and feel about content such as engineering. This includes what and how teachers learn and teach, which then influences what and how students learn.
Cope and Ward (2002) provide a representation of the associations between teachers’ perceptions of teaching and learning and students’ perceptions, learning approaches, and outcomes (Figure 1). This representation shows that how a teacher perceives K-12 engineering education will influence how that teacher believes engineering education should be learned and taught. This then influences what teaching approach is used, including the content approach, the context approach, the pedagogy approach, or a combination of these approaches. These decisions directly influence the approaches student will use to learn, which affects the quality and nature of students’ cognitive and affective learning outcomes. Gaining information on how preservice teachers understand and perceive K-12 engineering education is necessary to prepare future teachers to teach engineering in K-12 schools. Through the recognition of preservice teachers’ perceptions, teacher educators are provided with a starting point from which K-12 engineering education may more effectively develop.

Figure 1. Teacher Perceptions and Quality of Learning Outcomes (Adapted from Cope & Ward, 2002).
Summary

Studies examining the public’s understanding of engineering indicate that the public views the profession positively even though they do not fully understand what engineering is or what an engineer does (Davis & Gibbin, 2002; NAE 2008). Engineers were also viewed in stereotypical ways, being described as experts in math and science, nerds, myopic, or boring. Defining engineering as synonymous with construction was another common perception shared among the public as well as educators (Davis & Gibbin, 2002; NAE 2008; ASEE, 2006; Lambert et al., 2007).

The research literature shows that the degree to which inservice and preservice educators believe engineering education is important depends on teaching experience, preservice education, grade level, and subject area. Experienced teachers in science, math, and technology found engineering education to be important (ASEE, 2005; Baker, 2007; Lambert, 2007). While experienced teachers viewed engineering as important, they did not necessarily want to learn about how to include it in their teaching. The study conducted by Yasar et al. (2006) indicated that more experienced science teachers were less interested in learning about engineering education. Middle and secondary teachers were more likely to believe that engineering education is important when compared to elementary teachers (Yasar et al., 2006; ASEE, 2005; Hudson et al., 2009).

Perception plays an important role in how teachers understand engineering and engineers. The relationships between cognition and perception and perception and emotion determine how a teacher relates to the process and the content of learning engineering (Picard et al., 2004). How a teacher perceives the process of learning engineering influences his or
her perceptions of how to teach it. This influences how students learn engineering and ultimately determines the quality of their learning (Cope & Ward, 2002).

**Chapter Summary**

Currently K-12 engineering education discussions are centered on curricula, particularly secondary and technology education curricula. Scholars, educators, and curriculum developers are attempting to determine what a K-12 engineering curriculum should look like and how it should be implemented. There is a lack of consensus on this issue, but those involved in this discussion agree that engineering design should be a central feature of an engineering curriculum. While engineering design is a central feature of engineering education, it can be implemented in several ways depending on the approach chosen.

Three approaches can each be used as ways to address how to implement engineering education. Each may be used individually or they may be used in combination. Focusing on engineering content includes directly teaching the concepts and skills that are foundational to engineering. Using engineering as a context for teaching subjects such as science and math is another approach for implementing K-12 engineering curricula. Engineering content can still be present, but it is secondary with primary emphasis being on the context. Finally, an engineering pedagogy involves the use of specific teaching strategies that support the acquisition of engineering content and uses engineering context to support ways of thinking that are consistent with engineering epistemology.

The research literature on K-12 engineering education is not extensive. Few studies have been conducted that examine how the general public or K-12 educators understand engineering and engineers. The studies that have been conducted indicate that the public and
educators have a rudimentary understanding of engineering. For example, both educators and the public identified engineers as those who are proficient in math and science and construct objects. Several of the studies consisted of self-selected participants and examined perceptions after participants had completed a course or workshop on engineering education. These studies do not provide a complete representation of how average teachers may perceive engineering education. The pre-existing perceptions and prior knowledge that a teacher possesses guides the decisions they make in the classroom.

The instructional approach that an educator chooses for teaching engineering education depends on how she or he perceives engineering education. Teachers’ perceptions of learning and teaching influence the approach they take to teaching, which then influences how and what students learn. Understanding teachers’ perceptions is important as K-12 engineering education continues to develop. In particular, understanding the perceptions of preservice teachers can provide a firm foundation for teacher educators to develop effective instruction on engineering education.
CHAPTER 3. METHODS AND PROCEDURES

Assessing the perceptions that preservice elementary teachers possess regarding engineering and K-12 engineering education is a difficult task. Preservice elementary teachers are unlikely to have encountered engineering content or concepts in their undergraduate courses. Due to the near absence of K-12 engineering education in public schools, many of these future teachers may not have thought about engineering as a part of the elementary classroom. This lack of engineering experience and knowledge has important implications regarding the choice of research methods.

The lack of knowledge and experience that preservice elementary teachers may have with engineering makes it difficult to construct close-ended survey questions that would show the details, depth, range and nature of their knowledge and perceptions. Thus, to better understand preservice elementary teachers’ existing perceptions of engineering, this study employed qualitative research methods to gain data regarding the nature of preservice elementary teachers’ knowledge, perceptions and receptiveness towards K-12 engineering education. The purpose of this chapter is to describe the qualitative research methods used to conduct the study.

The chapter begins with an overview of qualitative research. After this a description of the participants and the context of the study is provided. Next, the procedures used for the study are described followed by methods used to collect the data. After data collection is discussed, an explanation of data analysis is provided. Finally, the role of the researcher and the study’s limitations are presented.
Qualitative Research Framework

Qualitative inquiry can refer to several research approaches, such as ethnography, naturalistic inquiry, narrative research, case studies, interpretive research, fieldwork, field studies and participant observation (Ary, Jacobs, & Sorensen, 2010). Qualitative inquiry focuses on the social context of human behavior. According to Ary et al. (2010), “Qualitative inquirers argue that human behavior is always bound to the context in which it occurs, that social reality cannot be reduced to variables in the same manner as physical reality, and that what is most important in the social disciplines is understanding and portraying the meaning that is constructed by the participants involved in particular social settings or events” (p. 420). Qualitative research aims to provide a rich description of how participants engage with and think about their environments.

Maykut and Morehouse (1994) provide an adapted framework for qualitative research based upon Lincoln and Guba's (1985) earlier work (See Figure 2). This framework provides a broad description of the structure of this study and consists of several components, with the first being a descriptive focus, noted in the framework as "focus on inquiry." A qualitative study aims to discover and deeply understand what experiences participants have had and their perceptions of those experiences. Due to the nature of discovery in a qualitative study, the research design is typically fluid and can change as the study progresses. As early phases of the data analysis are completed, new questions or situations can be identified that lead the research in unanticipated directions. Due to this aspect of emergent design, the framework becomes iterative.

Another key aspect of this framework is choosing an appropriate sample through purposive sampling techniques. Such techniques can be used to ensure variability in the
sample or to reduce variation if necessary. Once the sample has been selected, it is necessary to conduct the research in a setting that is familiar to the participants and relevant to the focus of the inquiry. According to Maykut and Morehouse (1994), "Personal meaning is tied to context" (p. 45). As a qualitative study progresses, data is collected in the forms of observations, interviews, field notes, and other artifacts such as audio and video recordings. The analysis of this data is ongoing and inductive in nature. As subsets of the data are collected, each are initially analyzed to identify potential new directions for the next subset of data. This inductive analysis can lead to a broadening or narrowing of the data. At the center of this framework is the "human-as-instrument" concept. This concept highlights the responsibility of the qualitative researcher

Figure 2. Maykut and Morehouse’s (1994) Adapted Framework for Qualitative Research.
as both the collector and interpreter of data. Finally, once the data analysis is complete, the researcher provides a rich description of the experiences and perspectives the participants shared along with an interpretation of what they mean to the study (Maykut & Morehouse, 1994).

**Interpretative Approach**

This study utilized an interpretative approach to qualitative research. According to Merriam (2002), "Learning how individuals experience and interact with their social world, the meaning it has for them, is considered an interpretative qualitative study" (p. 4). The interpretative approach focuses on understanding how people interpret and make sense of their personal experience (Cohen & Crabtree, 2006). The foundations of the interpretative approach to qualitative research lie in the social and human sciences. Unlike other qualitative research approaches such as ethnographic studies, which are rooted in anthropology, the interpretative approach has a broad foundation than cannot be tied to any one discipline within the social sciences. This broad foundation makes the interpretative approach suitable for wide variety of situations and data collection techniques, thus making it one of the most commonly used qualitative research approaches. Common characteristics of the interpretive approach include focusing on the participants' point of view, analyzing data through the identification of patterns or themes, and the rich description of participants' experiences and perspectives (Ary et al., 2010).

As stated by Maykut and Morehouse (1994), qualitative research seeks to investigate and respond to exploratory and descriptive questions. This study had an exploratory focus. The interpretative approach was used to explore the unfamiliar teaching and learning context that includes preservice elementary teachers and engineering education. An exploratory
qualitative study is useful for understanding unfamiliar social contexts such as this. In addition, exploratory qualitative studies can be used to test the feasibility of a more complex study or to add precision to a research problem (Frey & Fontana, 1993). The data gained from this study serve as a potential starting point for developing a more complex study designed to gather more generalizable information regarding preservice elementary teachers.

**Research Questions**

The purpose of this research study was to investigate how preservice elementary teachers’ approach engineering design, the perceptions of engineering and K-12 engineering education that they possessed, and their level of receptiveness with regards to K-12 engineering education. The following three research questions directed the study:

4. How do preservice elementary teachers approach an engineering design task?
5. What perceptions do preservice elementary teachers possess regarding engineering and K-12 engineering education?
6. To what extent are preservice elementary teachers receptive to engineering education?

**Preservice Elementary Teacher Participants**

The preservice elementary teachers that participated in this study were enrolled in a teacher education program at a large Midwestern university that is known for its engineering college. Participants were selected based upon their enrollment in a required senior level science methods course. Forty-six students were enrolled in the course and forty-four of these students participated in the study. Those that participated received participation points that contributed to their course grade. Students enrolled in this course had completed courses in mathematics teaching methods and instructional technology as well as courses designed to
increase their content knowledge in science and mathematics. These students had also completed their first teaching practicum, giving them some experience in an elementary classroom. A majority of the participants expected to complete their student teaching and then graduate within the next year. Six (13.6%) of the participants expected to student teach the following semester, and 32 (72.7%) expected to complete their student teaching after completing one more semester of courses.

This group of elementary preservice teachers was purposefully selected because of their formal experiences in their teacher education program. Due to the amount of formal education these participants had already completed, it was anticipated that they would provide the most informed responses when discussing teaching and pedagogy. According to Patton (1990), this purposefully homogenous sampling technique focuses the study, reduces variation, simplifies analysis and facilitates group interviewing. The purposive sampling technique supports the use of focus groups, which is the primary method of data collection in this study.

The students who participated in this study were predominantly female and white. Of the 44 participants, 41 (93.2%) were female. All 44 of the participants selected “white” when asked about their ethnicity. One participant also selected “Latino or Hispanic” and another selected “Asian or Pacific Islander.” With regards to age, most of the participants were between 20 and 23 years old. Thirty-five (79.5%) of the participants were 20-21 years old while five (11.4%) were 22-23 years old (See Table 2). All of the participants were majoring in elementary education. Only nine of the participants were working towards a minor area of study, with eight enrolled in a learning technologies minor and one enrolled in a child, adult, and family services minor. Table 3 shows the participants’ teaching endorsement areas.
Mathematics and reading were the most common endorsement areas. Nearly half (45.5%) of the participants were obtaining an endorsement in mathematics while 61.4% were working towards an endorsement in reading. Science endorsements were among the least common (two participants). Of the 44 total participants, 30 were obtaining more than one endorsement.

Participants working towards a math endorsement or learning technologies minor had the opportunity to take a course titled “Toying with Technology.” A course in both the materials and

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</table>
computer engineering departments, it was designed for and offered to education majors. In this course, students were exposed to the principles of technological innovations through the use of robotics and microcomputers (Toying with Technology, 2007). Nineteen (43.2%) of the participants had completed this course.

All participants were asked to indicate their experience with engineering and engineers. With regards to engineering, table 4 shows that more than half (56.8%) of the participants indicated that they had not had any real experiences with engineering. Twelve (27.3%) indicated that they had fixed simple machines around their home and ten (22.7%) indicated that they had taken engineering courses. The few remaining participants stated that

Table 3

<table>
<thead>
<tr>
<th>Area of Endorsement</th>
<th>Number of Participants</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>English and Language Arts</td>
<td>10</td>
<td>22.7</td>
</tr>
<tr>
<td>English as a Second Language</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>History</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>Mathematics</td>
<td>20</td>
<td>45.5</td>
</tr>
<tr>
<td>Music</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>Reading</td>
<td>27</td>
<td>61.4</td>
</tr>
<tr>
<td>Science</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Social Studies</td>
<td>6</td>
<td>13.6</td>
</tr>
<tr>
<td>Special Education</td>
<td>10</td>
<td>22.7</td>
</tr>
<tr>
<td>Speech/Theater</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>World Languages</td>
<td>2</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Note: *Participants could select more than one endorsement area.
they had competed in engineering competitions or provided their own connection to engineering.

Table 4

Participants’ responses to “Which of the statements below describe your personal experience with engineering?”

<table>
<thead>
<tr>
<th>Responses</th>
<th>Number of Participants(a)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have had no real experience with engineering.</td>
<td>25</td>
<td>56.8</td>
</tr>
<tr>
<td>I have fixed machines around my house, such as the lawnmower, dryer, computer, etc.</td>
<td>12</td>
<td>27.3</td>
</tr>
<tr>
<td>I have participated in engineering competitions, such as a robotics competition.</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>I have taken engineering courses.</td>
<td>10</td>
<td>22.7</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Completed Toying with Technology course (3)</td>
<td>3</td>
<td>6.8</td>
</tr>
<tr>
<td>• Attended engineering camp (1)</td>
<td>1</td>
<td>2.2</td>
</tr>
<tr>
<td>• Placed on engineering track during high school (1)</td>
<td>1</td>
<td>2.2</td>
</tr>
</tbody>
</table>

\(a\)Participants could select more than one response.

Table 5 shows that when asked about their experience with engineers, half of the participants indicated that they knew an engineer (50%), had a friend who was an engineer (54.5%), or had a family member who was an engineer (20.5%). Only nine (20.5%) of the participants indicated that they had no real experience with engineers. It was uncommon for a participant to state that they had previously been enrolled in engineering or to provide their own responses.
Table 5

Participants’ responses to “How much experience have you had with people who are engineers?"

<table>
<thead>
<tr>
<th>Responses</th>
<th>Number of Participants&lt;sup&gt;a&lt;/sup&gt;</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have had no real experience with an engineer.</td>
<td>9</td>
<td>20.5</td>
</tr>
<tr>
<td>I know people who are engineers.</td>
<td>22</td>
<td>50.0</td>
</tr>
<tr>
<td>I have friends who are engineers.</td>
<td>24</td>
<td>54.5</td>
</tr>
<tr>
<td>Someone in my family is an engineer.</td>
<td>9</td>
<td>20.5</td>
</tr>
<tr>
<td>I was once enrolled as an engineering major.</td>
<td>2</td>
<td>4.5</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Roommate was an engineer</td>
<td>1</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Note: <sup>a</sup>Participants could select more than one response.

Research Context: The Science Methods Course

The required science methods course for elementary preservice teachers was the primary context for this study. Forty-four students enrolled in two sections of the course in spring 2012 participated. Based upon the syllabus provided by the instructor, the science methods course is:
...a study of the underlying models of instruction, curriculum development, learning, assessment, and classroom management for teaching science. The course aims to develop prospective teachers’ personal teaching philosophies of the nature and importance of science education and how students learn science best according to research. The course emphasizes a practical and reflective approach to develop a community of active learners, how to design student-centered and inquiry-based curricula, and evaluate one’s own instructional practices.

The students enrolled in this semester-long course are typically juniors or seniors in the teacher education program. The course is divided into three parts: teaching science and inquiry in the classroom, a practicum experience, and reflection along with more instruction on science teaching methods.

The preservice elementary teachers enrolled in this course are required to complete several assignments throughout the semester including: weekly online journal entries, lesson plans, in-class whole group and small group activities, readings, observations, and a written book report. The major course assignments were the lesson plans and the written book report.

The science methods course served as an appropriate context for this study because it provided an environment in which questions and thoughts about K-12 engineering education seemed natural. The content of the course naturally extended and connected to ideas in engineering education. In addition, the science methods course focused on both state and national science education standards. The instructor of the science methods course was aware of the growing influence of engineering in science education standards. Thus, as part of the course, the preservice elementary teachers were required to participate in activities that contained elements from both science and engineering design. As the course began, students
were introduced to a science teaching model that they were expected to use throughout the semester as they completed all assignments.

The instructional model that was emphasized in the science methods course further strengthened the context for this study. During the first part of the course, students were introduced to the 5E instructional model as a way to teach science. As the semester progressed, students were expected to utilize this model as they developed lessons. The 5E instructional model (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook & Landes, 2006) contains five phases: engagement, exploration, explanation, elaboration, and evaluation.

During a regular semester, students in the science methods course are required to complete an in-class activity requiring the design of a toy-size parachute. However, during the semester in which this study occurred, students completed this activity twice. The first instance was a part of this study, while the second instance served as a way for students to revisit the activity and apply the 5E instructional model. While in the science methods course, the focus remained on the scientific concepts students could gain from participating in such an activity, but the second instance also provided a way to connect the phases of the 5E model to the engineering design process.

**Study Procedures**

The procedures for this study consisted of participants engaging in four activities: a journal entry, a demographic survey, an engineering design task, and focus group discussions. These data collection instruments were designed to be a part of the science methods course with the cooperation of the instructor. All of the data were collected during
the first five weeks of the semester. Introduced in the science methods course, the first journal entry was completed during the first week of the semester as a class assignment.

During the third week students attended focus group sessions where they first completed a demographic survey, then participated in an engineering design activity, and finally engaged in whole group discussion. The final journal entry was completed during the fifth week of the semester. Table 6 provides details on the sequence of events that took place during data collection.

Table 6

Sequence of Study Activities.

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants completed the first journal entry as part of the science methods course.</td>
<td>Participants signed up for 90 min. focus group times as part of the science methods course.</td>
<td>Participants attended focus group sessions where they completed the demographic survey upon arrival. They then participated in an engineering design activity that was then followed by whole group discussion.</td>
<td>Participants completed a follow up journal entry as part of the science methods course.</td>
</tr>
</tbody>
</table>

Journal Entries

The first activity participants completed was a journal entry. These journaling activities were built in to the course’s weekly online journaling assignments. Journaling activities were posted online using a course management system. For the study the
participants completed two journal entries. The first journal entry occurred during the first week of the semester. Participants were asked to respond to the following prompt:

Describe what engineering means to you. What do engineers do? Give some examples of things engineers produce. Engineering has been grouped with science, mathematics and technology as a part of education. What about engineering do you think qualifies it as a separate and distinct subject area in education?

**Demographic Survey**

Another source of data was a 10-item demographic survey (Appendix C). Upon arriving to the focus group, participants were given five to ten minutes to complete the survey. This time was in addition to the 90 minutes scheduled for the engineering design activity and focus group discussions. The survey was administered online via a survey-hosting website. Laptop computers were provided for participants to use so they could easily complete the survey before the focus group began.

**Focus Group Participation**

During the third week of the semester, students in the science methods course signed up to participate in one of six focus groups. The focus groups occurred after the first journaling activity and before the second. The focus groups were scheduled to occur during the evening on multiple days to minimize time conflicts with other courses or activities. Each student chose one focus group time that fit their schedule. The number of participants in each group varied. Two of the focus groups had five participants while the other four had 8-11 participants. The location for each focus group was a small classroom in the same building as their science methods course. This location was chosen because it is familiar to students and
it provided a quiet, professional environment where discussion could occur. The duration of each focus group was approximately 90 minutes.

**Engineering design activity.** Once the focus group began, students were first asked to participate in a brief engineering design activity. Participants were presented with the following scenario:

A cereal company wants to put a toy parachute in their cereal boxes. It has to be made out of simple materials: coffee filters, string and washers. They want to do this because they think it will help sell more cereal. The company would like the parachute to fall as slowly as possible because they think that will make it more fun. The job of your team is to figure out what affects the way a coffee filter parachute falls, design a coffee filter parachute, and then test your parachute. Your team will then make recommendations to the cereal company on how they should design their parachute.

The participants in each focus group were split into two to three teams and were given 40-45 minutes to design and test their parachutes. Each team was provided a ruler, scissors, tape, washers, coffee filters, string, and a laptop with a timer. Participants were video recorded during this time and observational notes were taken.

**Focus Group Discussions.** Once the design activity was finished, members of the focus groups sat down and were asked several discussion questions related to what they had just completed. This discussion took place over the course of approximately 45 minutes. The questions were broken into four discussion categories: content, context, pedagogy, and engineering town. The focus group questions and protocol appear in Appendix B. The questions in the engineering content discussion category were designed so that participants
would describe their parachute design approach, explain how their approach could be connected to engineering, and probe their understandings of design constraints and optimization. The second category, engineering context, was used to gain an understanding of how the participants connected the parachute activity to math and science concepts. In addition, this category asked participants about the classroom environment they felt was necessary for engineering learning. The engineering pedagogy category asked participants how they would teach engineering to their students, what they would expect to learn in a hypothetical engineering methods course, and how they felt about teaching engineering in their future classrooms. The final category, Engineering Town, was created as a fictional location where the population consists entirely of engineers. This was created as a way to frame questions regarding who can be engineer. The audio from these discussions was recorded for later analysis.

**Concluding Journal Entry**

The second journal entry occurred during the fifth week of the semester. At this point in the semester the participants were familiar with the 5E instructional model and had been working on developing a lesson based upon the model. Participants were asked to respond to the following prompt:

“Think about the process one must go through to design something, and explain specifically how this process could be used with the 5E model. What are the differences and similarities between designing activities, and using the 5E model? Describe as specifically as you can, ways in which these two disciplines can be integrated effectively into real K-8 science classrooms.”
Methods

The demographic surveys, initial journal entries, engineering design activity observations, and focus group discussions provided the data for this study. The methods used to collect these qualitative data were carefully planned to ensure that the data were credible and were directly related to the problem being examined. This study considered ways in which to help participants articulate their thoughts as well as the nature of the design activity, group dynamics, moderator behavior, questioning structure, environmental influences, and the role of the researcher.

Initial Journal Entries

The instructor of the science methods course facilitated the initial journaling activity. This included letting students know that the activity had been posted online and that they were expected to complete it. This journaling activity was designed to provide information about the participants’ knowledge of engineering and serve as a priming exercise for discussions regarding K-12 engineering education. Journaling served as a way to help participants articulate what they thought about engineering before attending the focus groups. According to Greenbaum (1998), “The best way a moderator can help the participants say what they really think and feel rather than be influenced by each other is to have them write down their opinions before sharing them with the group” (p. 144).

Focus Groups

The focus groups served as the primary means of data collection for this study. A focus group, or group interview, typically consists of eight to ten people brought together in a centralized location to respond to questions regarding a topic that is of particular interest to the researcher (Morgan, 1993). Compared to individual interviews, focus groups have several
advantages. First, because individual attitudes, beliefs, and values do not form in a vacuum, focus groups bring several different perspectives together and can help participants form and articulate their own thoughts and opinions (Ary et al., 2010). Second, the combined effort of the participants produces a wider range of information, insights and ideas. Third, Stewart and Shamdasani (1990) state that a “snowballing” effect can occur within focus groups. This occurs when a comment made by one participant triggers subsequent responses from other participants. Fourth, focus groups help prevent situations where a participant may be unwilling to share their thoughts or opinions because they are fearful that they may have to defend their views or that they may appear ignorant. Finally, a focus group can provide a greater level of comfort for participants, since the focus is on the group and responses are not necessarily being identified with individuals (Stewart & Shamdasani, 1990).

Due to the importance of these focus groups, several factors were taken into consideration to ensure that they were conducive to effective group discussion and data collection. These factors included the nature of the design activity, group dynamics, moderator behavior, question planning, and the study environment.

**Nature of the design activity.** The parachute design activity was based upon an activity found in the *Project Based Inquiry Science: Diving into Science* (Ryan, Kolodner, Holbrook & Crismond, 2010) physical science curriculum. This activity was designed to have upper level elementary students practice their design and investigation skills using concepts such as gravity, air resistance, and individual variable identification and manipulation. While the original activity had the instructor provide heavy scaffolding, for this study the activity was altered so that much of this scaffolding was removed. Focus group participants were instructed on what to design, but not provided any instructions as to how or
what scientific or mathematical concepts were relevant. This decision was made due to the exploratory and formative nature of this study. An unstructured design activity provided the opportunity to observe how participants approached the design process using only their prior knowledge and experiences. This also ensured that their later explanations of their design process were their own and not imitations of those provided by an instructor. The goal was to capture how participants worked through a design problem without being influenced by instruction regarding the engineering design process. This approach provided a clear representation of how participants personally conceptualized the process of design.

**Group dynamics.** According to Greenbaum (1998), the effectiveness of a focus group depends on how the participants interact with each other. Despite the nearly homogenous composition of the focus groups, steps were taken to encourage engagement by each participant. The first of these steps, providing nametags, is simple but important. Being able to address each participant by name helped build rapport within the groups and permitted questions to be directed to specific participants (Stewart & Shamdasani, 1990; Greenbaum, 1998). The nametags were used to help shape cohesive focus groups.

Initially, participants were asked to work together to design a parachute. While the primary purpose of this activity was to observe participants as they engaged in the activity, it also served a secondary purpose in that it increased group cohesiveness. Participating in shared experiences adds to the cohesiveness of the group. A focus group that is cohesive is likely to have increased verbal and nonverbal interactions and feel more satisfied with discussions (Stewart & Shamdasani, 1990). The design activity provided a shared experience for the participants that served as a foundation for the subsequent discussions. Other factors
such as gender composition and personality characteristics also influence the dynamics of a focus group.

Stewart and Shamdasani (1990) stated that the gender composition of a focus group heavily influences the depth of discussion and the extent to which mutual understanding can be developed. Each focus group in this study was predominantly comprised of females. Thus, it was necessary to ensure that male members had opportunities to participate in the discussion. This was done primarily through direct questioning. The advantage to this, according to Stewart and Shamdasani (1990), is that same-sex focus groups tend to be less conformist and provide a wider variety of responses compared to mixed-gender groups. In mixed-gender focus groups, leadership traits are more likely to emerge. This can lead to participants conforming to ideas presented by those displaying leadership (Dyson, Godwin & Hazelwood, 1976).

Each focus group was comprised of participants with different personalities. Participants’ personalities affected their willingness to contribute, their tendency to conform to others’ opinions, and the depth of their responses (Stewart & Shamdasani, 1990). All of these characteristics influence how a focus group functions. As the researcher, it was not possible nor my role to control these factors entirely. However, through the use of specific verbal and nonverbal communication techniques I attempted to maximize each participant’s willingness to contribute robust responses.

**Moderator behavior.** Of all the factors influencing the effectiveness of a focus group, the moderator is the most critical. According to Krueger (1993), an effective focus group moderator must project sincerity, have a sense of humor, be flexible, have a sharp memory and, most importantly, have the ability to listen. As the moderator, it was critical
that I was cognizant of both my verbal and nonverbal behavior as I conducted the focus groups.

The beginning of the focus group was used to set the tone and provided participants with a clear objective. Each group was introduced in a consistent manner based upon Krueger’s (1988) suggested introduction pattern. This pattern consisted of the welcome, presentation of the topic, stating of the ground rules, and finally the first question or activity. Participants were informed that they were asked to participate in the focus groups so that I could gain information related to their understandings of engineering and K-12 engineering education. As for ground rules, participants were asked to speak one at a time to ensure that everyone’s thoughts and opinions could be heard. During this introduction it was important to establish a sense of trust and openness by reassuring participants that their actions and responses would remain anonymous and that all opinions were valued (Stewart & Shamdasani, 1990).

During the initial parachute design activity, I utilized a strict non-directive interviewing style, interjecting only when necessary to keep the participants on task. The nondirective approach is an approach that allows for greater group interaction and discovery. Such an approach is beneficial because it provides greater opportunity for the participants’ views to emerge instead of having their views inadvertently shaped by those of the researcher (Stewart & Shamdasani, 1990).

After the design activity was completed, participants began their discussions. At this point in the focus groups it was necessary to transition to a more directive interviewing style due to the more structured nature of the discussions. This structure was the result of the questions I had developed for the group. In preparation for the focus group discussions, I
memorized the questions that needed to be asked and their order. This was done in an effort to maintain the flow of the discussions (Krueger, 1988). The additional structure during the discussions was also necessary due to the need to probe participants’ responses for further detail.

Probing, or asking follow-up questions after a participant has responded, was important because not all participants said all they would have liked to and some needed assistance to fully articulate their thoughts (Stewart & Shamdasani, 1990). Krueger’s (1988) suggestions for probing questions provided guidance for this study. These questions include:

“Would you explain further?”

“Would you give me an example of what you mean?”

“Would you say more?”

“Is there anything else?”

“Please describe what you mean?”

“I don’t understand.” (p. 83)

Probes such as these were used early in each focus group to emphasize the need for robust responses (Krueger, 1988). When a probing question was not required, other important strategies were utilized to acknowledge participants’ responses.

When responding to participants it was important to appear value neutral. For example, I avoided short verbal responses such as “excellent,” “correct,” and “good” because they imply judgment about the quality of a response, making participants more likely to continue responding in the same way. Instead, I used more neutral responses such as “OK” and “uh huh” (Krueger, 1988; Krueger, 1993). As for my nonverbal responses, I avoided nodding my head after responses to again prevent signaling agreement. Throughout each
focus group I monitored my body posture, facial expressions, and eye contact. While sitting among the participants I sat upright with my hands on the table (Bull & Brown, 1977), made eye contact with those who spoke, and made sure to smile (Kraut & Johnston, 1979). These nonverbal cues helped to ensure that participants felt I was welcoming and interested in what they had to say. Participants were also more likely to feel relaxed during the focus group due to these cues (Krueger, 1988).

**Question planning.** The questions (Appendix B) that were asked of the focus group members were carefully constructed. Questions were worded using language that participants could easily understand. Engineering-specific terms that might have been unfamiliar were intentionally removed. Long, multi-part questions were also avoided to prevent confusion among the participants (Stewart & Shamdasani, 1990).

The sequencing of the questions was also taken into consideration. The discussion began with concrete questions related to the initial design activity and gradually became more abstract as the focus shifted from the engineering content in the design activity to engineering as a context, followed by engineering pedagogy. The final set of questions were more specific, asking participants to conceptualize a town populated only by engineers to determine what they perceived as engineering culture and who is suitable for engineering. The questions built upon each other, often referencing the initial parachute design activity. This sequence helped maintain a firm context for the focus group participants to think about engineering and K-12 engineering education (Krueger, 1988; Stewart & Shamdasani, 1990).

Participants were given flexibility in their responses due to the way the questions were structured. Each question was designed using an open-ended structure, which according to Krueger (1988), encourages participants “to respond based on their specific situation” and
it “reveals what is on the interviewee’s mind” (p. 60). Such open-ended questions are likely to generate responses that participants find most important or salient, which is important information in studies where existing theory and literature are underdeveloped (Stewart & Shamdasani, 1990). Questions were also structured according to their primacy. The ten primary questions were asked first in order to introduce new ideas or topics. If participants needed further direction on a primary question, corresponding secondary questions were used to facilitate further discussion (Kahn & Carnell, 1964).

**Environmental influences.** The final factor that was considered to maximize the effectiveness of the focus groups was the environment in which they took place. Two classrooms were used to conduct the focus groups to reduce scheduling conflicts. Each room was located in the same building as the science methods course, making it easy for participants to locate. These rooms contained tables, chairs, and presentation technologies such as a TV or document camera. None of these technologies were utilized for the focus groups. The near absence of distractions in these rooms served as a way to focus participants’ attention on the discussion (Stewart & Shamdasani, 1990).

The arrangement of the rooms was another important environmental factor. Tables in these rooms were arranged in a circular pattern. Participants sat around the tables so that they could easily see and interact with each other. According to research done by Steinzor (1950), communication among group members who are seated in this way is significantly greater than other seating configurations.

**Follow-Up Journal Entries**

The instructor of the science methods course also facilitated the follow-up journal activity during week five of the semester. The purpose of the second journaling activity was
to understand how the instruction they had received in their science methods course may or may not have altered their thinking regarding the parachute design activity. These data were collected for later research that is beyond the scope of this study. This is due to the data being summative in nature. This journal entry data were influenced by classroom instruction in the science methods course, meaning that participants’ initial perceptions of engineering and design may have been altered.

**Role of the Researcher**

A crucial part of any qualitative research study is the instrument that is used to collect and analyze data. According to Lincoln and Guba (1985), a human is the only research instrument capable of capturing the complex, subtle, and constantly changing situations that are part of the human experience. As the primary data collection instrument, it was important that I acknowledged any potential biases that could have influenced the results of the study. Once identified, it was necessary to find ways to mediate these potential biases as best as possible.

Prior to conducting the research for this study, I taught an introductory course on digital learning for two years. The level of undergraduate student enrolled in this class varied, but they tended to be at the beginning of their coursework in the teacher education program. The participants selected for this study were upper level students who may have previously been enrolled in my digital learning class. I had also worked with several students as part of my role in a technology center. The potential for bias in this situation stems from favorability. As moderator, I was at risk of favoring the views or comments of those I am familiar with, with those who were strangers having an increased likelihood of being overlooked. Preventing such bias required a non-partial attitude and a keen awareness of my
verbal and nonverbal responses. Specific tactics used to prevent this bias included being patient, permissive and encouraging to all participants, probing all participants for further elaboration, and providing consistent comments to all participants (Stewart & Shamdasani, 1990).

Another important aspect of my experience worth recognizing is the fact that I am not an engineer. I began my undergraduate career as an engineer, but after a year I chose to pursue a degree in elementary education. This means that my knowledge of engineering is limited and that I may hold misconceptions regarding the profession. Such misconceptions can cause problems when interpreting data that focused on engineering. While my understanding of engineering was likely more sophisticated than those of the participants, it is not equivalent to that of a professional engineer. These potential biases were prevented from influencing this study by relying heavily on the research literature. The literature provided information regarding what engineering is and what engineers do. This information was used throughout the planning, implementation, and analysis phases of this study.

Finally, the predominantly female composition of the focus groups must be discussed. Having a male moderator for focus groups that contain mostly female members goes against the suggestions of Krueger (1988) and Axelrod (1975). Krueger notes that it is important for the moderator to appear like the participants in both dress and appearance. According to Axelrod (1975), having a male moderator and female participants can lead to discussions that are less natural and an increased likelihood that responses are aimed at pleasing or impressing the moderator. While not all of the focus groups were 100% female, this was still an issue of concern. The nondirective interviewing style (Stewart & Shamdasani, 1990) mentioned previously served as a way to decrease the effects of having a male moderate
predominantly female focus groups. I emphasized the notion that the focus group discussions were not necessarily discussions between those in the group and myself, but rather discussions among the members themselves. My role was to provide direction for the discussions by posing questions, interjecting only when I felt clarification or elaboration was needed. This behavior was more likely to create an environment where my role as moderator was de-emphasized, thus making it less likely that female participants would find it necessary to tailor their responses to my presence.

**Data Analysis**

The written, verbal, and visual data collected in this study were analyzed using conventional content analysis. According to Hsieh and Shannon (2005), conventional content analysis consists of inductively developing categories and codes after repeatedly examining the data. This analysis is useful when there is limited research literature or existing theory available, as is the case in K-12 engineering education (Hsieh & Shannon, 2005). To code in qualitative research is to review the data and “dissect them meaningfully while keeping the relations between the parts intact” (Miles & Huberman, 1994, p. 56). The codes themselves are labels used to assign units of meaning to “chunks” of information gathered from the study, whether it is descriptive or inferential (Miles & Huberman, 1994). These chunks can vary in size, ranging from a few words to whole paragraphs.

The coding process was iterative. First the data were examined and initial thoughts and comments were noted. Subsequent examinations led to the identification of data that were representative of key thoughts. These key thoughts were identified through regularities in the data (Patton, 1980). These key thoughts then led to the development of codes. The initial organization and coding of the data were refined as the analysis progressed. Individual
codes were clustered together based upon the relationship the codes had with each other (Hsieh & Shannon, 2005). This technique was advantageous because the data fit tightly to the codes that represented them and it allowed for a greater sensitivity to the context of the study (Miles & Huberman, 1994).

Written journal entries and comments made during focus groups were transcribed and entered into NVivo. NVivo is a software application that supports the organization and analysis of qualitative data. This software facilitated the content analysis by increasing the speed at which data could be organized and coded. In addition, it managed the data sources that coded items originated from, making it possible to see how specific codes were represented across data sources.

Observational notes taken by the researcher while participants engaged in the engineering design task were used to develop the initial categories of participant actions and perceptions regarding engineering. The video recordings of participants engaged in the engineering design task were reviewed several times and the actions and comments from each group were coded and entered into the observation categories that were refined as this process progressed.

The results of the demographic survey were compiled and analyzed. The frequency counts from the survey provided a demographic profile of the participants (see tables 2, 3 and 4). This demographic profile was used to gain an understanding of participants’ prior experiences with engineering and engineers.

**Credibility**

A challenge in qualitative content analysis is failing to develop a complete understanding of the context. This failure then leads to the development of categories and
codes that do not accurately represent the data. In qualitative research, this problem is referred to as “credibility” or “internal validity” (Lincoln & Guba, 1985; Miles & Huberman, 1994). The data sources in this study were triangulated to ensure that the analysis for this study provided credible results.

The variety of sources of data in this study provided the means for credibility through triangulation. Triangulation can be used to correlate multiple qualitative data sources within a qualitative study. According to Patton (1980), this means comparing observational data with interview data, comparing private responses to public responses, checking for consistency of what people say about a situation over time, and comparing the perspectives of people with different viewpoints. In this study, the observational data recorded from the parachute design activity were compared to the focus group discussions. The private journal responses were also compared to the public responses provided by the focus group discussions. Table 7 shows that each research question was answered using at least two different sources of data.

Table 7

*Amount of Data Used From Each Data Source for Each Research Question*

<table>
<thead>
<tr>
<th>Written Data (Journals)</th>
<th>Approaches to an engineering design task</th>
<th>Perceptions of engineering and engineers</th>
<th>Perceptions of K-12 engineering education</th>
<th>Receptivity towards K-12 engineering education</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NA</td>
<td>66%</td>
<td>33%</td>
<td>NA</td>
</tr>
<tr>
<td>Observational Data</td>
<td>100%</td>
<td>20%</td>
<td>NA</td>
<td>20%</td>
</tr>
<tr>
<td>(Design Task)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral Data (Focus Group</td>
<td>12.7%</td>
<td>15.6%</td>
<td>54.4%</td>
<td>20.1%</td>
</tr>
<tr>
<td>Discussions)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* The same data were used to answer more than one research question. Thus the totals of some columns and rows exceed 100%.
This served as a way to compare and crosscheck the consistency of information that was collected at different times using different means. Patton explains that the “consistency in overall patterns of data from different sources and reasonable explanations for differences in data from different sources contributes significantly to the overall credibility of the findings presented” (Patton, 1990, p. 331).

The content analysis led to the development of several codes that were used to indicate key patterns of thought throughout the data. These codes and the relationships that existed between codes were used to complete the data analysis. This information is presented in chapter four.

**Reliability**

The issue of reliability in qualitative research is concerned with whether the process of a study was consistent and stable over time (Miles & Huberman, 1994). Miles and Huberman (1994) state that the research questions should be clear and align with the study design, the researcher’s role and status should be clearly defined, and that findings should show “meaningful parallelism” across participants and groups. The research questions in this study served as the developing framework for the questions that was used during the focus groups (See Appendix B). These questions were used for each focus group. My status and role was clearly defined at the beginning of the data collection. Participants were informed that I was interested in their perceptions of engineering, that I was not there to teach them anything, and that there were no right or wrong responses.

**Study Limitations**

This study had limitations that must be considered before any conclusions are drawn from the data. The context of the study contributed three limitations in that the study took
place at a university known for engineering, occurred in one geographic area, and lacked a diverse sample of participants. In addition to contextual limitations, having friends sign up for the same focus groups was limiting.

While the context of the study takes place in a science methods course within a teacher education program, the larger context was a university known for engineering and technology. This larger context meant that participants may have had more experience with or exposure to engineering than the average preservice elementary teacher. The context was also restricted to the Midwest region of the United States. The geographic location of the university also limited the amount diversity among participants. The assumed experience of the preservice elementary teachers was also a limitation. Upper level students were targeted due to their increased experience and the likelihood that they would be more informed discussants regarding teaching and learning. However, using upper level students did not guarantee an upper level understanding of learning and pedagogy.

The use of focus groups was limiting as well. While the participants in each focus group did not necessarily know all of the other members, several participants were friends with each other. These friends chose to enroll in the same section of the science methods course and subsequently chose to sign up for the same focus group. Templeton (1987) explains that friends in focus groups can endorse each other’s views and create an imbalance of opinion. This limitation was unavoidable because it was not possible to determine who were friends and participants had the freedom to select their own focus group time.

The limitations that were present in this study were typical of qualitative research. In qualitative research such limitations are often unavoidable. While little can be done to avoid
these issues, as the researcher it was important for me to be cognizant of these limitations as I conducted the study and data analysis.

**Chapter Summary**

This study employed qualitative research methods to examine the perceptions preservice elementary teachers possessed regarding design, engineering, and K-12 engineering education. The framework by Maykut and Morehouse (1994) provided the foundation for the study design. An interpretative approach was used to understand how participants within a science methods course made sense of their experiences with engineering and design.

The required science methods course served as an appropriate context for this study because it provided an environment in which thoughts about K-12 engineering education seemed natural. The data collection instruments for this study were designed to be a part of the science methods course.

Forty-four preservice elementary teachers participated in the study. These participants were selected because they were upper level students in a teacher education program and therefore had a greater likelihood of providing robust responses to questions regarding teaching and learning. Data were collected from these participants by first using journal entries, then demographic surveys, followed by parachute design task observations, and finally focus group discussions.

Data were collected while taking several factors into consideration. These factors included the nature of the design activity, group dynamics, moderator behavior, questioning structure, environmental influences, and the role of the researcher. As the primary research
instrument, it was important that I prevented previous acquaintances, prior knowledge, and gender issues from influencing the data collection and analysis.

The collected data were analyzed using conventional content analysis. The content analysis led to the inductive development of codes that identified central themes and patterns within the data.

Finally, this study was limited by the larger context in which it took place, the assumed experience of the participants, and the fact that some participants were friends. As the researcher, it was important that I be aware of these issues but not try to control them.
CHAPTER 4. RESULTS

The purpose of this chapter is to present the results of this qualitative investigation of preservice elementary teachers’ perceptions of engineering and their receptivity to K-12 engineering education. To address the research questions, data from four sources were analyzed: written journal entries, demographic survey, researcher observations of participants engaged in an engineering design task, and focus group discussions.

This chapter is divided into five sections. Because the focus groups served as the nexus of the research activities, the first section provides an overview that examines how much time participants in each focus group spent discussing each topic. The remaining sections present the results regarding the three research questions.

Participants’ Use of Time During Focus Group Discussions

Once transcribed, the focus groups generated 126 pages of data. This large pool of data was utilized to answer the research questions. Specific portions of focus group data were used to address corresponding research questions. Examination of the amount of time the preservice elementary teachers spent talking about each discussion category provided a broad understanding to what the preservice teachers gave emphasis to. This illuminated what participants had knowledge to talk about and felt comfortable discussing. In addition, it provided a context for interpreting the data and addressing the research questions.

The questions that were asked of participants during the focus group sessions were divided into four discussion categories: engineering content, engineering context, engineering pedagogy, and Engineering Town (See Table 7). Engineering content focused on the design process participants used during the parachute design activity. Engineering context examined how participants connected the parachute task to math and science and the
classroom environment they believed was necessary for engineering. Engineering pedagogy items asked participants about engineering teaching strategies and methods as well as their

Table 8

Focus Group Discussion Categories and Questions

Engineering Content
1. How did you go about creating the parachute? What was your process?
2. How might the parachute activity be related to engineering?
3. Imagine that you want to mass-produce your parachute as a product people would buy. How would this influence or change your parachute design?

Engineering Context
4. How might the parachute activity be used to teach math and science lessons?
5. Imagine a classroom that the parachute activity could take place in. What does it look like?

Engineering Pedagogy
6. Imagine you are having your future students complete the parachute activity. How might you teach them your design process?
7. STEM (science, technology, engineering, mathematics) education has been receiving a large amount of national attention due to its importance. However, as a preservice teacher you take methods courses in science, math, and technology but not engineering. Why do you think there is no engineering methods course? What do you think you would learn in an engineering methods course?
8. How do you feel about using teaching methods that include engineering design in your future elementary classroom? To what extent do you believe a K-6 student is capable of solving an engineering problem using design?

Engineering Town
9. What does an engineer look like in this town? What are their ways of doing things? What is their culture? Who is there or not there?
10. How many of your future students will make it to Engineering Town? What will be your role in getting them there?
attitudes towards K-12 engineering education. Finally, the questions in the Engineering Town category were used to probe how participants perceived engineers and how participants believed they could encourage their students to become engineers.

To gain an overview of the content and perspectives of the preservice elementary teachers as expressed in the focus group discussions, an analysis of the amount of time that each group spoke about each discussion category was conducted. The results of this analysis are provided below. The length of focus group discussions ranged from 38 minutes to 47 minutes with the average time being approximately 43 minutes (See Table 8). Engineering pedagogy consumed nearly 50% of focus group discussions while engineering content received the least amount of discussion (μ = 5:28 min or 12.7% of time).

Table 9
Time Each Focus Group Spent on Each Discussion Category (in min and sec)

<table>
<thead>
<tr>
<th>Focus Group Discussion Categories</th>
<th>Focus Group 1 N=4</th>
<th>Focus Group 2 N=5</th>
<th>Focus Group 3 N=6</th>
<th>Focus Group 4 N=11</th>
<th>Focus Group 5 N=9</th>
<th>Focus Group 6 N=9</th>
<th>Avg. Time and %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Content</td>
<td>5:10 (12.0%)</td>
<td>5:43 (13.2%)</td>
<td>4:52 (12.0%)</td>
<td>5:02 (10.8%)</td>
<td>5:38 (14.7%)</td>
<td>6:22 (13.5%)</td>
<td>5:28 (12.7%)</td>
</tr>
<tr>
<td>Engineering Context</td>
<td>7:25 (17.2%)</td>
<td>8:26 (19.5%)</td>
<td>5:47 (14.3%)</td>
<td>8:46 (18.9%)</td>
<td>7:04 (18.5%)</td>
<td>7:18 (15.4%)</td>
<td>7:28 (17.3%)</td>
</tr>
<tr>
<td>Engineering Pedagogy</td>
<td>19:51 (46.1%)</td>
<td>20:46 (47.9%)</td>
<td>22:59 (56.7%)</td>
<td>17:54 (38.6%)</td>
<td>12:24 (32.4%)</td>
<td>25:46 (54.5%)</td>
<td>19:57 (46.0%)</td>
</tr>
<tr>
<td>Engineering Town</td>
<td>10:36 (24.6%)</td>
<td>8:25 (19.4%)</td>
<td>6:55 (17.1%)</td>
<td>14:42 (31.7%)</td>
<td>13:12 (34.5%)</td>
<td>7:52 (16.6%)</td>
<td>10:17 (24.0%)</td>
</tr>
</tbody>
</table>
Engineering Pedagogy Discussions

Engineering pedagogy received the most discussion time. Tables 8 and 9 indicate that the focus groups spent an average of approximately twenty minutes on this portion of the discussion. This accounted for nearly half (46%) of the discussion time on average. The discussions on engineering pedagogy centered on how the participants might teach engineering in their elementary classrooms (engineering teaching strategies: $\mu = 7:04$ min, 16.3%) and how they feel about engineering education (attitudes towards engineering: $\mu = 8:45$ min, 20.1%).

Engineering Town Discussions

Discussions about Engineering Town accounted for an average of 24% of the discussions ($\mu = 10:17$ min) and were second only to engineering pedagogy. Participants were asked about who would be in a town populated entirely by engineers and the culture that such a town would have. When discussing Engineering Town, participants spent more time discussing the characteristics of who would be there and what the town would look like ($\mu = 5:31$ min) compared to explaining how they might get their future students there ($\mu = 4:46$ min).

Engineering Context Discussions

Engineering context accounted for an average of 17.3% of the discussions ($\mu = 7:28$ min). The discussion on engineering context included discussing what math and science topics were connected to the parachute design activity and what an elementary engineering classroom would look like. Participants tended to more readily discuss what an engineering
### Table 10

*Time Each Focus Group Spent on Each Discussion Question (in min and sec)*

<table>
<thead>
<tr>
<th>Discussion Categories</th>
<th>Questions Asked During Focus Groups</th>
<th>Focus Group 1</th>
<th>Focus Group 2</th>
<th>Focus Group 3</th>
<th>Focus Group 4</th>
<th>Focus Group 5</th>
<th>Focus Group 6</th>
<th>Avg. Time and %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Content</td>
<td>Design Process</td>
<td>1:32 (3.6%)</td>
<td>2:15 (5.2%)</td>
<td>2:22 (5.8%)</td>
<td>2:48 (6.0%)</td>
<td>2:56 (7.7%)</td>
<td>1:12 (2.5%)</td>
<td>2:11 (5.1%)</td>
</tr>
<tr>
<td></td>
<td>Design Task’s Connection to Eng.</td>
<td>0:58 (2.2%)</td>
<td>1:13 (2.8%)</td>
<td>0:35 (1.4%)</td>
<td>1:08 (2.4%)</td>
<td>1:46 (4.6%)</td>
<td>1:24 (3.0%)</td>
<td>1:11 (2.8%)</td>
</tr>
<tr>
<td></td>
<td>Additional Design Considerations</td>
<td>2:40 (6.2%)</td>
<td>2:15 (5.2%)</td>
<td>1:55 (4.7%)</td>
<td>1:06 (2.4%)</td>
<td>0:56 (2.4%)</td>
<td>3:46 (8.0%)</td>
<td>2:06 (4.8%)</td>
</tr>
<tr>
<td>Engineering Context</td>
<td>Connections to Math and Science</td>
<td>2:50 (6.6%)</td>
<td>3:55 (9.0%)</td>
<td>2:47 (6.9%)</td>
<td>4:52 (10.5%)</td>
<td>1:36 (4.2%)</td>
<td>3:32 (7.5%)</td>
<td>3:15 (7.4%)</td>
</tr>
<tr>
<td></td>
<td>Engineering in the Classroom</td>
<td>4:35 (10.7%)</td>
<td>4:31 (10.4%)</td>
<td>3:00 (7.4%)</td>
<td>3:54 (8.4%)</td>
<td>5:28 (14.3%)</td>
<td>3:46 (8.0%)</td>
<td>4:12 (9.9%)</td>
</tr>
<tr>
<td>Engineering Pedagogy</td>
<td>Engineering Methods</td>
<td>5:53 (13.7%)</td>
<td>9:12 (21.2%)</td>
<td>4:20 (10.7%)</td>
<td>1:22 (2.9%)</td>
<td>1:36 (4.2%)</td>
<td>2:24 (5.1%)</td>
<td>4:08 (9.6%)</td>
</tr>
<tr>
<td></td>
<td>Engineering Teaching Strategies</td>
<td>6:05 (14.1%)</td>
<td>4:51 (11.2%)</td>
<td>7:07 (17.6%)</td>
<td>5:42 (12.3%)</td>
<td>6:38 (17.3%)</td>
<td>12:00 (25.4%)</td>
<td>7:04 (16.3%)</td>
</tr>
<tr>
<td></td>
<td>Attitudes Toward Engineering</td>
<td>7:53 (18.3%)</td>
<td>6:43 (15.5%)</td>
<td>11:32 (28.4%)</td>
<td>10:50 (23.3%)</td>
<td>4:10 (10.9%)</td>
<td>11:22 (24.0%)</td>
<td>8:45 (20.1%)</td>
</tr>
<tr>
<td>Engineering Town</td>
<td>Engineering Town</td>
<td>6:03 (14.1%)</td>
<td>4:37 (10.7%)</td>
<td>5:27 (13.4%)</td>
<td>8:24 (18.1%)</td>
<td>5:16 (13.8%)</td>
<td>3:16 (6.9%)</td>
<td>5:31 (12.8%)</td>
</tr>
<tr>
<td></td>
<td>Getting to Engineering Town</td>
<td>4:33 (10.6%)</td>
<td>3:48 (8.8%)</td>
<td>1:28 (3.6%)</td>
<td>6:18 (13.6%)</td>
<td>7:56 (20.7%)</td>
<td>4:36 (9.7%)</td>
<td>4:46 (11.2%)</td>
</tr>
</tbody>
</table>
classroom would look like ($\mu = 4:12$ min) compared to identifying relevant math and science concepts related to the design activity ($\mu = 3:15$ min).

**Engineering Content Discussions**

All six of the focus groups spent the least amount of time discussing questions related to engineering content and the parachute design task. On average, each of the focus groups spent approximately five and half minutes discussing this portion of the focus group questions (12.7%). The questions in the engineering content category were related to the design process participants used for their parachutes, how the parachute design task is connected to engineering, and the identification of additional design considerations if their parachutes were to be mass produced. Within the engineering content category, participants spoke the most when asked to describe the design process they used during the engineering design activity ($\mu = 2:11$ min or 5.1% of time). Participants spoke the least when asked to describe how the parachute activity is connected to engineering ($\mu = 71$ sec or 2.8% of time). Focus group three discussed this question for the shortest amount of time at 35 seconds.

**Connections Across Focus Group Discussion Responses**

The discussion questions were intentionally ordered to facilitate a seemingly natural and logical discussion. During analysis, however, connections across responses emerged. As was stated, engineering pedagogy received the most discussion time ($\mu = 20$ min or 46% of time); and within this category, the question examining engineering teaching strategies consumed 16.3% or 7 minutes and 4 seconds of time. Yet discussion regarding getting students to Engineering Town (in the Engineering Town category) averaged only 4 minutes and 46 seconds (11.2%). This connection was most pronounced when examining focus group three. This group discussed engineering teaching strategies for approximately seven minutes
(17.6%) but discussed getting students to Engineering Town for a minute and a half (3.6%). Since getting students to Engineering Town requires engineering teaching strategies, the expectation was that the time spent on these two questions would be similar.

Another connection that emerged concerned the engineering context category. The “connections to math and science” question was the focus of discussion for an average of 3 minutes and 15 seconds. However the “engineering in the classroom” question consumed more attention ($\mu = 4:12$ min). This may have been due to participants needing to understand more content in order to identify relevant math and science concepts. Visualizing an engineering classroom did not require specific content knowledge, which may have been why participants discussed the “engineering in the classroom” question to a greater extent. This was most evident in focus group five, where connections to math and science were discussed for 1:36 min (4.2%) while engineering in the classroom was discussed for 5:28 min (14.3%).

**Research Question 1: How Do Preservice Elementary Teachers Approach an Engineering Design Task?**

The first research question aimed to operationalize participants’ understanding of engineering design through a hands-on activity. Participants in each focus group were divided into subgroups and asked to complete an engineering design task. This design task consisted of a short scenario that had participants imagine they were designing toy parachutes for a cereal company. Participants were provided with string, coffee filters, tape, scissors, rulers, and laptops (stopwatch website used for timing). The following was read to the participants before they began the task:
A cereal company wants to put a toy parachute in their cereal boxes. It has to be made out of simple materials: coffee filters, string and washers. They want to do this because they think it will help sell more cereal. The company would like the parachute to fall as slowly as possible because they think that will make it more fun. The job of your team is to figure out what affects the way a coffee filter parachute falls, design a coffee filter parachute, and then test your parachute. Your team will then make recommendations to the cereal company on how they should design their parachute.

This scenario was based upon an activity found in the Project Based Inquiry Science: Diving into Science (Ryan, Kolodner, Holbrook & Crismond, 2010) physical science curriculum. The scenario and the materials were presented to the participants. They did not receive any special instruction or guidance as they designed their parachutes. Four of the six focus groups were split into subgroups to complete the design task for a total of 11 design task subgroups. Each of these subgroups was analyzed individually.

Participants spent an average of forty-two and a half minutes on the design task. The researcher observed the participants during the design task and noted their initial actions and approaches. These served as the initial basis for categories of activity within the design task. The subsequent analysis of the design task videos resulted in the identification of five categories of activity during the design task: participants' behavior at the beginning of the task, design progression, degree of precision, tone of participants as they worked, and participants' behavior at the end of the design task.

Once the design task was completed, participants were asked to actively contribute to a discussion comprised of four categories: engineering content, engineering context,
engineering pedagogy, and Engineering Town. The engineering content category was directly related to the design task participants had just completed and questioned students on: the process they used to design their parachutes, how the design task might have been related to engineering, and other aspects of their designs that they would need to account for if they planned on creating parachutes for a large number of cereal boxes.

The content analysis of the focus group discussions coupled with the categories of activity from the researcher observations and videos led to the derivation of inductive codes. Eight codes emerged that describe participants design approach: decisions driven by prior experience, recognition of design constraints, need for precision, weak rationalizations, non-design related concerns, additive design process, procedures over process, and overly complicated designs.

**Design Task Findings: Results of Video Recording Analysis and Observations**

**Participants’ behavior at beginning of design task.** Once participants had gathered their materials, many approached the design task with enthusiasm and became immersed in assembling their parachutes. Several of the teams within the focus groups immediately began to propose design ideas, tape coffee filters together, cut string, or drop coffee filters to watch them fall. As a whole, participants did not spend a significant amount of time discussing or planning their parachute designs. After observing the participants complete the design task it became apparent that most participants either trivialized the activity or let the novelty of the activity take precedence over careful analysis and planning. Those who trivialized the design task saw it as something they had to do, so immediately began assembling a parachute with little planning. The remaining participants became so immersed in constructing their parachutes that they neglected to develop solid plans and analyze their design decisions.
Design progression, degree of precision, and tone. Trivializing the design task and focusing on constructing the parachutes at the expense of analysis both led to teams developing many different designs at a rapid pace. However, due to the lack of analysis participants often modified or changed their parachute designs without fully considering how their most recent design performed before making the alterations. Participants recognized there were only a few aspects of their design that they could change, including: number of coffee filters, arrangement of coffee filters, length of strings, number of strings, arrangement of strings, number of washers, methods of attaching string to the filters and washer (tape vs. tying), and the porosity of their parachute. Participants commonly would change one of these design aspects not because of how their parachute performed but because they recognized these design aspects as something that could be changed. In other words, instead of discussing what aspect of their design may have been producing poor performances participants chose to rapidly change design aspects because it was something they had not tried yet.

Participants’ behavior at the end of the design task. Due to the lack of planning and analysis, participants struggled to come to a conclusion at the end of the design task. After rapidly developing several designs with no single design outperforming the rest, many groups slowed down, became quieter, or suggested changes that were based upon even less analysis. Once groups had tried changing the design aspects mentioned previously, many were unsure of what to do next since they could not determine which of their designs was superior. This also led to groups inquiring how much longer they needed to work on the task or how much time they had left. The participants who became overly immersed in
constructing their parachutes often ran out of time, preventing them from fully testing the performance of their parachutes.

**Design task summation.** Overall, the design task videos, researcher observations, and the first three focus group discussion questions indicated that most of the preservice elementary teachers displayed no deliberate design process when engaging in an engineering design task. Instead, participants utilized a process more closely aligned to trial and error. However, while several trials were attempted by the focus groups, the identification and analysis of errors in connection to the trials was minimal. Despite the lack of a clear design process, the analysis did indicate that these preservice elementary teachers recognized some factors that are involved in engineering design. While recognizing some design factors, several others were overlooked.

Participants recognized that prior knowledge, constraints, and precision have roles in the engineering design process. Participants frequently stated that they relied upon prior knowledge while completing the design task. Once asked about additional design considerations, such as those that would need to be considered for manufacturing, participants noted several design constraints (e.g. size of the cereal box) and stated that they would need to improve the precision of their design process.

Despite the recognition of these design factors, participants displayed several patterns that were indicative of an incomplete understanding of engineering design. Participants had difficulty rationalizing their design decisions using science and math concepts and often discussed aspects of their designs that were not related to function. When problems arose with their designs, participants often attempted to provide solutions using an additive method. That is, they continually added more materials or features to their designs.
Participants did not articulate the difference between process and step-by-step procedures and often referred to their design process as a specific list of procedures they did. Finally, many participants’ designs were overly complicated.

Triangulation of the researcher observations, video recordings, and focus group discussions illuminated how the preservice elementary teachers approached an engineering design task. The preservice teachers’ approaches emerged in two patterns: recognition of relevant engineering design factors and issues of concern related to engineering design. A complete reporting of each pattern is reported below.

**Recognition of Relevant Engineering Design Factors**

While the participants in the study had little experience with engineering and engineering design (according to the demographic survey results), they were able to identify or discuss three relevant factors related to design. These factors included the use of prior knowledge, design constraints, and precision.

First, participants made several comments on the importance of prior knowledge and experience and using these to inform the design process. For example, one student explained her approach:

“I was thinking…in terms of what did I learn in physics last semester. …I was trying to apply what I knew already to this to see if that would help it.”

During the design task participants often used words such as “air resistance,” “gravity,” “stable,” or “symmetry.” Participants saw these as relevant and attempted to use these concepts. However, when participants discussed using prior knowledge it typically was not in reference to any particular scientific concept.
Participants’ use of prior knowledge was limited by their lack of experience with engineering design. Their use of prior knowledge primarily consisted of recalling parachutes they had seen before while their understandings of concepts related to air, gravity, and weight were used to a lesser extent. Statements such as the following were common responses when asked to describe their design process:

“I thought of what a parachute looks like…what I know a parachute looks like and tried to think of…oh like the strings are all attached to like the little guy.”

“I mean that’s how we were doing it, saying ‘Oh, I wonder what a parachute looks like’ and then trying to recreate that.”

The second relevant design factor participants cited was constraints. Participants identified several relevant design constraints when asked about mass-producing their parachutes. Many groups discussed using less material to reduce costs, the size limitations imposed by the cereal box, and making their method of assembly more efficient or simpler:

“Like how much materials are going into it, so how possibly a bigger…parachute would have more time in the air, but it wouldn’t be effective to make more like that, cause it would cost too much.”

“…we’re probably going to have to [consider] size because we’re going to have to put it in a package of some sort.”

While participants articulated these constraints during the focus group discussions, it is worthwhile to note that these constraints rarely were discussed as groups were designing and assembling their parachutes during the design task. For example, one student noted that her team’s use of trial and error was not the best process based upon the constraints:

“…probably use less trial and error…I mean none of us are obviously parachute developers, but um, there is a cost to developing a product and there are costs to, you know, the actual equipment that you need to build it, and to do those trial and errors, and the more you do the more it is going to cost, and it comes down to cost a lot…”
The third relevant factor of design that participants identified was precision. As with the recognition of design constraints, participants recognized precision as a necessary element during the focus group discussion but did not apply it during the design task. Several groups lacked precision during the design task, neglecting to time their parachute drops, measure the length of their strings, or maintain a constant drop height. As the focus group discussions began, participants’ comments reflected the trivialization and lack of analysis discussed previously. Lack of precision emerged as a common talking point. Several teams admitted to “winging it” or basing their design evaluations on observation instead of measurement. For example:

“We’d have to make sure you measure the length of the string, making sure its right in the middle of the circle…and you’d have to know how many, because we didn’t count how many of the actual materials we used…”

“We didn’t have much planning, just put it together…and try again.”

“Our [was] more winging it…we didn’t really have a [plan]…you guys sounded like you had a plan of what you were going for…”

However, as participants began to discuss teaching with a design task such as the parachute activity they recognized that precision was necessary. Participants commented on how engineering requires precision and that this should apply to an engineering classroom activity as well:

“When I think of engineering, they have to have everything, you know, exactly right for it to work, like bridges and everything. So with parachutes you have to have everything working perfect for it to fall the slowest or whatever, everything has to be precise.”

“I don’t think it would be as chaotic. I think it would be more precise. You would be discussing outside factors and you would be calculating that into what you’re doing. Like it would be a precise process…it wouldn’t be like just…some activities and its trial and error…”
Issues of Concern Related to Engineering Design

Participants recognized the importance of prior knowledge, relevant design constraints, and the need for precision despite not fully utilizing these factors themselves while engaged in the design task. In addition, several other patterns emerged from the coding process that highlight the participants’ approach to engineering design. These patterns included weak rationalizations, non-design related concerns, additive design processes, procedures over processes, and overly complicated designs.

A common issue across most groups was weak rationalizations or explanations of design decisions. Participants used weak or loose understandings of scientific concepts to defend their design decisions. This occurred in five of the six groups. For example, during the design task one group proposed putting a washer on the top of their parachute. They thought that by adding more weight to the top of the parachute it would make it harder for the bottom washer to pull the additional weight, therefore slowing it down. When asked to explain their design decisions, participants often struggled to explain how scientific concepts were relevant:

“Because I mean the air going through the hole versus the air getting caught is going to make it go up more so that it would fall slower.”

“So we didn’t think about size, but we thought of how it had to have, like, air resistance or wind resistance, like to keep it up, not pull it straight down.”

Another common issue dealt with non-design related concerns. Four of the six groups spent time discussing aspects of their design such as making the parachute colorful, putting a cartoon character at the bottom, or how to market it. These aspects may have been important when attempting to sell their design, but they were not relevant to how their design functioned.
Additionally, when describing their design processes, four of the six focus groups described a process where design failure meant adding more materials or features to the design. Several participants were of the mentality that if the design was not working something was missing and should be added. This included adding more coffee filters, more string, more washers, more tape, or poking more holes in their parachute. An example of this pattern is provided in this participant’s description of their design process:

“…at first we had holes in between the filters, that didn’t work so then we covered those up and we tried one with just three, didn’t work, so then we tried a fourth, still didn’t work. Umm and then we went from tying the string to the washer to taping the string to the washer and that didn’t work either.”

The descriptions that participants provided for their design processes led to the emergence of another issue as well. When asked to describe their design process, four of the six groups listed out procedures or recalled, step-by-step, what they actually did instead of providing a process that includes why and how decisions were made. For example:

“We went through trial and error basically, we just tried, like, first we tried a lot of coffee filters then we tried, you know, a few, and then we tried big, then we tried like curled. So we just went through [and] tested everything I guess.”

“I didn’t really go in order, but I guess you’d like put a string on a small one, and then tie the washer to the small one, a couple of the small ones, and then put the big one on top so it is wider. But the string is like further in the middle of the parachute maybe.”

The final issue participants struggled with was making their designs unnecessarily complicated. Only two groups actually commented on this. However, this pattern was observed across several groups. The authors of the original task planned on having students use one coffee filter, one washer, two pieces of string, and some tape. However, while completing the design task groups tended to start complicated and work their way back to simple. This included designing a seven-filter parachute with multiple strings by one group.
Other groups chose to intricately tie the strings to their parachutes instead of using tape. One group assembled a “triple parachute” that included three individual parachutes arranged vertically and all attached with string. These decisions were not necessarily based on anything they had observed from testing their designs or their own experience.

**Summary: Preservice Elementary Teachers’ Approach to an Engineering Design Task**

The recognition of prior knowledge, design constraints, and precision as factors related to engineering design suggests that the preservice teachers possessed a rudimentary understanding of design. However, these factors were primarily discussed during the focus group discussions and after completing the design task. While the preservice teachers recognized these factors as relevant, they did so as an afterthought. During the design task preservice teachers more commonly displayed patterns that were not representative of engineering design.

The most salient finding from the engineering design task is that the preservice elementary teachers did not utilize any deliberate design process when engaging in a design task. This lack of deliberation stemmed primarily from their inability to firmly rationalize their design decisions. Being unable to provide strong reasons for making decisions, the preservice teachers instead focused on what they did during the activity instead of why. Without understanding the “why” behind their decisions, the preservice teachers relied on extraneous ideas to continue the design activity. This included non-design related concerns such as adding more features or materials to a design without reason. This additive design method in turn led to overcomplicated designs.
Research Question 2: What Perceptions Do Preservice Elementary Teachers Possess Regarding Engineering and K-12 Engineering Education?

The second research question in this study sought to understand engineering perceptions held by preservice elementary teachers. Perceptions are ways of understanding, regarding, or interpreting concepts, and influence how a teacher views learners and learning, teaching, subject matter, learning to teach, and themselves as teachers (Calderhead, 1996). A teacher’s perceptions ultimately affect what and how students learn. Thus, the perceptions a teacher possesses regarding engineering content and pedagogy influence their approach to teaching engineering. Teaching approaches directly influence student learning, which then impacts the quality of students’ learning outcomes (Cope & Ward, 2002). Understanding how preservice elementary teachers perceive engineering and K-12 engineering education, as well as how their perceptions of these concepts are linked, provides a foundation for further developing K-12 engineering education.

To answer this research question, data were collected from multiple sources. These sources included journal entries, observations of the parachute design task, focus group discussions, and a demographic survey. The research question was divided into two distinct questions to report the results:

1. What perceptions do preservice elementary teachers possess regarding engineering and engineers?

2. What perceptions do preservice elementary teachers possess regarding K-12 engineering education?
What Perceptions do Preservice Elementary Teachers Possess Regarding Engineering and Engineers?

The data regarding participants’ perceptions of engineering as a profession and engineers as people were collected primarily from two sources. The first source included an initial journal entry that participants completed before attending the focus groups. Participants were asked to respond to the following prompt:

Describe what engineering means to you. What specifically do engineers do? Give some examples of things engineers produce. Engineering has been grouped with science, mathematics and technology as a part of education. What specifically about engineering do you think qualifies it as a separate and distinct subject area in education?

The second source was the focus group discussions. The last portion of the focus group discussion questions centered on a fictional environment called Engineering Town. During these questions, participants were asked to imagine a town populated entirely by engineers. They were also asked to describe what an engineer in this town looks like, how they do things, and the culture of the town.

The data from the initial journal entry provided an understanding of how participants viewed engineering as a profession while the Engineering Town questions provided an understanding of how participants perceived engineers as people. In addition, participants made relevant comments regarding the perceptions of engineering and engineers during other focus group discussion questions. For example, when asked how the parachute design task was related to engineering, participants often made comments that included perceptions of engineering as a profession.
Perceptions of Engineering as a Profession

The analysis of perceptions of engineering as a profession included three parts: definition of engineering, outcomes of engineering, and how engineering is done (See Table 10). Overall, the data indicated that preservice elementary teachers defined engineering as a profession that focuses on design and construction. There were 20 comments related to the perception that engineers are directly responsible for construction across both the focus groups and the journal entries. While most participants attempted to provide a definition for engineering, several did not do so. In a total of 12 comments, participants listed types of engineering (e.g. mechanical, civil, etc.) or admitted that they did not really know what engineering was. Whether participants provided a definition or not, most responses regarding the definition of engineering were simplistic and brief.

Participants viewed the outcomes of engineering as products. Participants emphasized products and gave little attention to systems and processes. With regards to how engineering is done, participants emphasized trial and error (19 comments). However, participants also stated that creativity and efficiency were two central factors in how engineering is done. According to these participants, engineering’s primary purpose was to build products as efficiently as possible or take existing products and make them better or more efficient. A complete reporting of these results appears below.

Definition of engineering. According to Katehi, Pearson, and Feder (2009), engineering involves modifying the world according to the wants and needs of people. This includes developing plans and directions for how artifacts, processes, and systems are to be constructed or implemented. However, Katehi et al. (2009) note that engineers do not
typically construct these items themselves. The participants recognized that engineering involves design, but many defined engineering as a profession that does include the literal construction of artifacts. For example, after making a comment that distinguished between people making plans and people implementing plans, one participant said the following of the people implementing the plans:

“They’re still doing that. None of them have the formal education because the ones that do are in the office and creating the blue prints. But I mean, I always still, I guess, consider them engineers because they’re out digging in the dirt.”

Other participants did not make this distinction so clear, but also commented on how engineering involves design as well as construction:

“Engineering to me means building and constructing things…at least I think so.”

“I imagine people designing and constructing machines…”

Table 11

*Perceptions of Engineering as a Profession: Frequency of Comments per Pattern Across Individual Focus Groups and Journals*

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Focus Group 1 (N=4)</th>
<th>Focus Group 2 (N=5)</th>
<th>Focus Group 3 (N=6)</th>
<th>Focus Group 4 (N=11)</th>
<th>Focus Group 5 (N=9)</th>
<th>Focus Group 6 (N=9)</th>
<th>Journal Entries</th>
<th>Total Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emphasis on construction</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>Define engineering using types of engineers</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Emphasis on Products</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>Trial and Error</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Efficiency</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>Creativity</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Total Comments</td>
<td>10</td>
<td>5</td>
<td>2</td>
<td>13</td>
<td>6</td>
<td>11</td>
<td>63</td>
<td>110</td>
</tr>
</tbody>
</table>
“Engineers are constructors, designers, and builders.”

Other participants experienced difficulty when asked to explain what engineering meant to them personally. Along with briefly using words such as “create” and “design,” these participants often attempted to answer the question by providing a list of specific types of engineering. For example:

“I have not had many experiences in my life with any type of engineers…I have found that there are many different areas of study in the engineering field. There is electrical, chemical, software, constructive, materials, mechanical, nuclear, and aerospace engineering. I had no clue that there were so many!”

“To be honest I’m not sure what engineering is. I know there are electrical, computer, civil, and chemical engineers. I have met a few chemical engineers and they too couldn’t explain what it is they do.”

Comments such as these provide an indication that participants lacked a specific understanding of engineering. Engineering was perceived as being very similar to construction despite the mention of design. Participants were more willing to elaborate upon the notion of engineering involving construction than they were when mentioning design. If a participant could not provide a clear definition they often resorted to listing the types of engineering they had heard of.

**Outcomes of engineering.** In the definition provided by Katehi et al. (2009), it is stated that engineering does not only include the planning and designing of artifacts but of systems and processes as well. The participants’ focused primarily upon products without considering systems and processes. In addition, participants often discussed similar products. The products commonly identified by participants were roads, bridges, buildings, machines, and other physical objects.
The examples that participants provided tended to be common things that they had experienced. While it is common to see bridges, houses, and buildings being built it is less common to see a chemical being developed or a computer network being planned. In addition, nearly everyone experiences a multitude of machines on a daily basis, which is perhaps why so many cited machines as an example of engineering.

**How engineering is done.** In addition to discussing the nature of engineering and the products that engineering produces, participants also discussed how these products are produced. Based upon the participants’ performance during the parachute design task and the focus group discussions, it became apparent that the majority of the participants believed engineering is accomplished through trial and error. Participants stated that this was how they approached the parachute design task and also how they believed engineers approach their own design problems. Examples of participants’ statements included:

“…just trial and error, like using different things to see what works better and what doesn’t.”

“Engineering anything is just trial and error.”

“We just kind of did trial and error. I feel like we worked on different [parachutes], and just saw how the results were varying.”

“You go with it and you start with something and you build off of the things you find and the things you figure out as you go along.”

“Engineering, there’s no right answer, you can’t check anything, its just taking what you have, designing something, and then…done with it.”

These statements also suggest that the participants did not utilize any formal design process during the parachute task. However, these statements also indicated that participants perceived this trial and error as a legitimate approach used in engineering. Few participants saw any problems when asked to compare their design approach to that of an actual engineer.
Along with trial and error, participants also viewed engineering as a profession requiring the use of efficiency. These participants expressed that engineering was a profession concerned with producing or modifying objects in the most efficient manner. These participants made comments such as:

“…designing new, better, efficient ways or seeing something that works but trying to make it better.”

“Seeing a problem and trying to figure out what to do, like the most efficient way.”

“Engineering is making things more efficient and better, and so that is what we were doing.” (Referencing parachute design task)

“I feel like engineering has a lot, a lot, of emphasis on efficiency. I mean I know, um, technology is supposed to make things more efficient but I feel like a huge, huge, portion of engineering is making things more efficient, to make products more efficient, to make manufacturing more efficient, that’s pretty much processes, but just, a huge huge part of it, at least in my experience and my experience with engineering. It’s about improving upon what’s already there or continuing to improve and continuing to make things more efficient.”

“I see engineering as a way of connecting ideas to the world to make things more efficient.”

While these participants perceived efficiency as an important component of engineering, they did not elaborate as to how engineering could make things more efficient. Participants strongly associated the profession of engineering with trial and error and efficiency, but only a small number associated engineering with creativity.

Creativity was mentioned less frequently as participants shared their understanding of engineering. Those who did discuss creativity felt that this concept is what set engineering apart from other professions and content areas (e.g. science and math). These participants made statements such as the following:

“[Engineering] must combine structured science and math with creativity and flexibility. It takes a special person to master these semi-opposing skills.”
“I believe that the creative and design aspects of engineering are what set engineering apart…”

“Rather than being straightforward and rote, engineers must learn to try new things and be innovative with their work.”

“The discipline of engineering is double-sided, in that there must be stringent procedures and guidelines fed by innovation and creativity.”

The previous statements indicate that not only do these preservice elementary teachers view engineering as a creative endeavor, they also view other mathematical and scientific professions as rigid, inflexible, and unimaginative. It was common for participants to state that engineering has no right or wrong answers, both in the journal entries and during the focus group discussions.

As a profession, participants perceived engineering as consisting of constructing and designing new products in an efficient manner. In addition, some viewed engineering as requiring creativity to produce such products. This emphasis on products indicated another pattern related to participants’ understanding of engineering as a profession. That is, participants possessed a narrow view of the items engineering produces in that they gave little attention to systems and processes.

**Perceptions of Engineers As People**

When discussing engineers as people, participants’ comments were organized into two categories: who can be an engineer and the culture that engineers create. Discussions on who could be an engineer tended to center around two claims: being an engineer typically meant being a man; and everyone could be considered an engineer. Participants who made the claim that everyone could be an engineer viewed problem solving as an engineer’s main
task and stated that everyone has to solve problems; thus, everyone could be called an engineer.

Few participants were willing to comment on race or ethnicity when discussing who could be in Engineering Town. Those who did comment stated that they envisioned most of Engineering Town’s population being white men. While hesitant to discuss ethnicity, participants provided several comments regarding personality characteristics. Engineers were commonly described as being both cooperative and competitive. While not as common as the cooperative and competitive patterns, some participants also viewed engineers as perfectionists and/or socially awkward.

**Who can be an engineer?** During the focus group discussions on Engineering Town, participants had the opportunity to describe who was in this imaginary town. The goal of the Engineering Town questions was to reveal how participants perceived engineers with regards to gender, race, and personality characteristics. Responses to these questions indicated that participants perceived engineers as predominantly male. For example:

“I guess when I picture an engineer without thinking, like, everybody in the town is a man, and like, buttoned up shirt and khakis, something like that. I know there are women engineers too, but just not as many.”

“I mean I think anybody in general can be an engineer, when I think engineer I do think more men I think.”

“I think there’s more, like right now anyways, there’s more guys that are engineers.”

“It is a male dominated field, like there is no denying that it is a male dominated field.”

While commenting on gender was not an issue for most participants, the issue of race was discussed far less frequently. Only two of the six focus groups discussed race. It is unclear if participants felt uneasy discussing this topic or if the issue simply did not occur to
them. Some participants that discussed race did not necessarily see it as an important issue, either because they believed it to be a non-issue in modern times or because they believed Iowa was not representative of the diversity found in other locations. Statements regarding race included:

“Umm as far as gender and ethnicity go, I’d say anyone could be, its just like when you think of engineers or like back in the day it was typically white male you know and like even in our [university] now we’re seeing a lot more females get into engineering and I just feel like anyone’s capable of being an engineer. It was just like typically white male before so…”

“This is terrible to say, but it’s the honest truth, like, looking demographic wise, ethnicity wise, then that’s going to cut out certain types of people, because, you know, predominantly white, middle class people go to college, have all the education, end up with the good jobs…”

“If you’re in a town in Iowa then its probably dominantly white, but I mean, anywhere else I think it could be anyone.”

“Well I think it’s hard to think of what, because here, the only ones we really see are the male, white, so its hard to imagine elsewhere, like, what other races and characteristics they are.”

“I see a lot of the Asian culture with it, or from India…”

Another pattern when discussing who could be in Engineering Town was the notion that everyone could be there. This pattern was as common as the pattern concerning engineers predominantly being men. Participants who felt this way believed that everyone must solve problems at some point in their life, and engineers solve problems; therefore, everyone could be considered an engineer and everyone could be in Engineering Town. However, despite the perception that everyone could be an engineer it is worth noting that women and minorities were not explicitly discussed as being a part of Engineering Town. For example:
“I mean if you think about it, everybody is an engineer. Everybody asks why, everybody tries to problem solve, everybody tries to figure out a better way to do something…”

“I think we’re all engineers in a way…because I mean in order to survive in this world you have to be somewhat of an engineer and you have to have some critical thinking skills, you have to be able to figure out problems or I mean you’re not going to make it very long.”

“I think they would be just like I us. Like I mean all of my engineer friends are fairly normal, like there’s a few that are negotiable but I mean for the most part they’re like…you and I. I mean heck I could be a genius for all you know and I just chose teacher.”

“I don’t know if this is cheesy, but I think everyone’s an engineer. I mean, anybody can problem solve, that is what engineering is to me, problem solving to help other people and make society better, so like if everyone’s working together that’s what I picture it as, everyone is working together to make better ideas.”

A few participants were even willing to call themselves engineers after completing the parachute design activity. Participants who perceived engineers in this way typically had a very broad perception of engineering.

In Engineering Town, participants typically saw mostly men or everyone living in the town. While some participants did note that engineers are typically white males, race and ethnicity was not a widely discussed topic across the focus groups. After participants discussed who could be an engineer, the discussions shifted to the culture that the residents of Engineering Town would cultivate.

**Culture of engineers.** Along with describing who they believed would be in Engineering Town, participants also described the culture of the town. Overall, participants provided slightly contradictory perspectives on this matter. Many participants believed Engineering Town would be a cooperative community while also believing that a strong
element of competition would exist. Some participants believed this competition would stem from a need for perfection. Remarks on cooperation consisted of statements such as:

“They’re a big community, like we were talking about, like when you do activities in groups it builds community, so they’re close and open to each other I feel like.”

“Collaborative. I mean I know you still have to consider personalities but I don’t know I still think it’d be collaborative, I think that people would collaborate.”

This issue of personalities became a frequent discussion point among the groups despite several viewing Engineering Town as having a cooperative culture. Participants felt that a town full of engineers would cause some to attempt to outperform each other, leading to competition.

“Everyone’s going to kind of want to get their way…”

“I think it might be hard to get along because I feel like there’s always a leader and then there would be another leader and you’d have people get butting heads but then you’d have some passive people that if you’re an engineer and the other person next to you, and you think you know best…”

“They might clash a little bit, different ideas. I know I live in a fraternity full of engineers, and it gets quite heated sometimes…”

This competitive nature that the participants discussed led some of them to the idea that engineers are perfectionists. A few participants commented on how the yards in Engineering Town would be perfectly maintained, everything would have a place, and the town would be well organized. These ideas then led a small number of participants to discuss stereotypical views of engineers.

While discussing the culture of Engineering Town, a few participants perceived engineers as being socially awkward or lacking social skills. These participants believed that without social skills, a community such as Engineering Town would experience some difficulties. These comments included:
“Like they’re socially awkward because they spend kind of like, along the line of like neurosurgeons because they spend so much time learning what…they do that their social skills just aren’t there, which again is stereotyping and bad but it’s just kind of how I envision them.”

“I don’t know, it’d have to be some give and take and if some people don’t have any social skills they might argue, I don’t know. It’ll either go nowhere and they’ll just be treading water or they’ll be really successful.”

“There’s a lot of sandals with socks.”

“They’d build things, they’d create things, but you could have the smartest person in the world and have no social skills…”

There was some joviality when comments such as these were made, so it was not always clear if participants actually believed these perceptions or if they were simply attempting to lighten the mood in what had been predominantly serious discussions. At the very least, comments such as these indicate that the participants were aware of some stereotypical views of engineers.

**Summary of Perceptions of Engineering and Engineers**

The definitions that preservice elementary teachers provided for engineering indicated that they perceived engineering as a profession responsible for the construction of products. If participants could not provide a definition for engineering they listed types of engineering instead. Participants saw the outcomes of engineering being physical products that they had experienced before. These products included items such as roads, bridges and machines. Regarding the methods used by engineering to produce such products, participants stated that trial and error is how engineering is done. Participants also recognized the importance of efficiency and creativity in how engineering is done.
What Perceptions do Elementary Preservice Teachers Possess Regarding K-12 Engineering Education?

The data for this question came primarily from focus group discussions. The discussion surrounding the topic of K-12 engineering education stemmed from five primary questions during the focus groups:

1. “Imagine you are having your future students complete the parachute activity. How might you teach them your design process?”
2. “What do you think you would learn in an engineering methods course?”
3. “To what extent do you believe a K-6 student is capable of solving an engineering problem using design?”
4. “How many of your future students will make it to Engineering Town?”
5. “What will be your role in getting your students to Engineering Town?”

Participants’ responses were organized using two main categories: elementary students as engineers and elementary teachers teaching engineering. The “elementary students as engineers” category focused on how the participants envisioned elementary students in a classroom learning engineering concepts. This category was subcategorized based upon comments about the likelihood that students could succeed in engineering, students’ prior knowledge of engineering, and the actions that students would perform in an engineering classroom.

The second category, “elementary teachers teaching engineering,” focused on how the participants envisioned themselves teaching engineering concepts in an elementary classroom. This category was further organized into the following subcategories: teacher
actions, engineering classroom culture, providing encouragement for pursuing engineering, integrating STEM content, and needs for teaching engineering.

**Students of K-12 Engineering Education**

The preservice elementary teachers were unable to provide detailed or specific information on what student learning would look like in an elementary classroom that includes engineering. The same held true when participants were asked to describe their role as a teacher in such a classroom. Participants stated that the success their future students may have in engineering was dependent upon the difficulty of the engineering content and grade level. When asked to set contextual concerns aside, participants believed that their future students had a strong chance of succeeding in engineering. A small number of participants believed this success would be a result of students already possessing knowledge relevant to engineering. The majority of participants believed that students would be responsible for directing their own learning when engaged in engineering content. This was evident not only when participants described student actions in a hypothetical engineering classroom, but also when they described the actions that they themselves would perform as the teacher. A complete reporting of these results appears below.

**Likelihood of students becoming engineers.** Overall, participants felt that their future elementary students would be quite capable of succeeding in engineering. However, several noted the importance of tailoring the engineering content so that it was developmentally appropriate. This concern for age and grade level was the primary concern for many participants:

“Just depends on, I think they could do it. As long as there is not a ton of restriction on them and I mean you’re going to have to give younger kids probably more guidelines and offer more help for them.”
“It just sort of depends on like on how difficult of a task you’re asking them to complete. I think almost any grade level could work on this type of a problem.”

When participants were asked how many of their future students would actually make it to Engineering Town and become professional engineers, their responses indicated both idealism and realism:

“‘I’d hope several, because I taught them. Education is important, but the bottom line I say very few.’”

“We would hope all of them, but realistically I don’t know if that would be.”

“Well I’m just going to say that I don’t know if introducing engineering, I mean it might make a little bit of a difference, but kids are going to be who they want to be.”

“I don’t know, why not all of them? If the teachers are teaching them what they need to know I guess.”

“If your getting this kind of engineering methods in the elementary grades, kids grow up loving going to the classroom just so they can create stuff, design stuff, test stuff, and then in high school they learn an engineer gets to do this everyday and get really rich, so yeah, I want to do that, I think you could get a lot of them.”

“I’d like to say all of them if they’re interested and having everyone strive to get there if they want it…I guess.”

Of the participants who were optimistic about their students’ capabilities in engineering, some possessed this optimism due to their belief that students could be viewed as “natives” to engineering just as young students have been called “digital natives” with regards to technology.

**Engineering natives.** While discussing students’ capabilities in engineering, three of the six focus groups linked their perceptions to how students use technology. These participants subscribed to the “digital native” idea. This idea proposes that because current students have never known a time without digital technologies they are quite comfortable
with using these technologies and are more knowledgeable about them than someone who
did not grow up with such technology (Prensky, 2001). Participants who expressed this idea
felt that their students’ knowledge of technology would make them more likely to succeed in
engineering and would also make them more capable in engineering than the teacher; thus
making the students “engineering natives.” For example:

“I couldn’t begin to build a robot at all ever but these kids put it together and figured
it out and so I think it is just a difference of lifestyle and what you’re taught and what
you know.”

“They’ll bring in more of the technology aspect because I mean they’re using it so
much often compared to when we were in school like so they’ll have that background
knowledge you know to incorporate [them] and then you can always modify stuff I
mean depending on the age level I feel like.”

“When I was in class and we had to go to the school and have the student like do
some of the projects that we did and when I did them I was like oh my gosh that is
really hard I don’t think you know like a fourth grader is going to be able to do that
like if I can barely do it but then when we got there they were coming up with crazy
models and they were really good at everything even like the computer parts that
were kind of harder they were like really they just caught on really quick.”

The perception that students would be quite capable of successfully learning engineering, and
in some instances more capable than the teacher, influenced the actions that participants
envisioned students performing in an engineering elementary classroom.

**Students’ actions in an engineering classroom.** The preservice elementary teachers
were unable to provide many specific actions that they envisioned elementary students
performing while completing an engineering design task. The student actions that were
described indicated that the participants thought that the students themselves would be
responsible for much of their own learning:

“You could have them like Google parachutes and then have them maybe have a
better mental image of what it looks like and see if they can come with ideas [that
are] similar that would work for them.”
“They would have to just explore it, kind of not have like a whole lot of direction on it, and then go into all these different things that would affect it.”

“I see kids just getting the materials that you have sitting on the middle table or in one central area, to coming and going and getting the materials and then going off in their groups and, wherever they’re comfortable, getting down on the floor, at the tables, start building.”

These student actions were indicative of the actions participants envisioned themselves performing as teachers. Since most participants felt that students would be taking the lead, the participants felt that their actions as a teacher would minimal.

**Teachers of K-12 Engineering Education**

The perceptions that participants possessed regarding K-12 engineering education were divided into five subcategories: teacher actions, engineering classroom culture, providing encouragement to pursue engineering, STEM integration, and needs for teaching engineering successfully. An overview of the findings is presented below, followed by a more detailed account of the results for each subcategory.

The discussions surrounding elementary students in an engineering classroom and teachers in an engineering classroom overlapped when participants mentioned specific actions that both students and teachers would perform in the classroom. Overall, participants believed that engineering instruction would be taught through hands-on and exploratory activities. Due to this perception, participants saw students exploring materials with little guidance from the teacher. Along with describing the actions they would perform in an engineering classroom, participants also described the type of instructional environment that they believed would be necessary and how they would encourage students to pursue engineering.
If engineering were to be taught in an elementary classroom, participants felt that the typical classroom would need some cultural adjustments. Due to their perception that engineering is a profession that requires teamwork and collaboration, participants felt that they would need to establish a strong student-led community in an engineering classroom. Participants described a classroom environment that includes engineering as very “hands-on” and “student-led.”

When asked how participants would get their students to Engineering Town, several provided vague responses. During this discussion participants often stated that they would simply encourage students to learn about engineering or expose them to the idea of engineering. When asked what this encouragement or exposure would look like in the classroom, participants struggled to provide specific answers.

Participants also discussed how they thought engineering could fit into their elementary teaching and what they felt they would need to be successful. As participants discussed engineering methods, several felt that the most realistic approach to including engineering in their teaching would consist of integration with math and science. Engineering was viewed as a way to make connections among the STEM subjects and participants also felt this would work better in time-constrained classroom.

Finally, participants expressed their needs to successfully teach engineering in an elementary setting. Several indicated that they were not entirely opposed to an additional course in their teacher education program. Some indicated that an “integration” course would be useful to understand how the STEM subjects can be integrated with each other. Others indicated that they would like hands-on activities to practice what their students would be doing. Participants also wanted specific and meaningful engineering activities that students
could do and information on how to properly facilitate such activities. A complete reporting of these results appears below.

**Teachers’ actions in an engineering classroom.** Participants stated that they would be minimally involved while students were learning due to the perception that an engineering design task would need to be student-led. A common response among the participants was that engineering should be exploratory, meaning students are provided with the necessary materials and trusted to complete the task on their own. For some participants, this “letting the students go” was the only teaching action they anticipated:

“You don’t have to necessarily say ‘Use this,’ I mean you can kind of let them explore.”

“[Let them] figure it out and then just kind of walk around the room and watch them.”

“The teacher doesn’t really do any guiding or anything, just say the instructions and say alright now go explore.”

“…and kind of with that, give them a concrete experience, maybe have an actual parachute, I don’t know, just play with it and then go to something else from there.”

Other participants stated that they would need to be more involved. While most of these participants also felt exploration was important, they also recognized that as teachers they would need to ask guiding questions and facilitate discussions.

“I mean assuming that you’re going to have a learning goal for the activity, like you need to have really direct, specific guiding questions for your students, like, not telling them the answer, but like ‘Oh, what would happen if you changed this part?’ or ‘What happens if you drop it higher?’ or ‘Why don’t you try it?’”

“Like, ‘Why did you do this?’ or ‘Did you think about this?’ or ‘Have you thought about using this, the string or the tape?’ Just help them transition in their thinking.”

“We could you know have the discussion of a group that only used two coffee filters and a group that used eight or whatever and compare their results and say why do we think that more coffee filters was better and kind of take the choices from the students and you know compare them.”
Engineering classroom culture. Discussions on how to teach engineering led to discussions that focused on the type of classroom environment or culture that participants felt would be necessary to teach engineering. Hands-on learning, student-led learning, and the freedom to make mistakes were provided as the defining characteristics of an engineering classroom. These characteristics were not necessarily unique to K-12 engineering education.

While comments regarding hands-on learning, student-led learning, and the freedom to make mistakes were common, participants did not elaborate upon these concepts. These concepts were stated in a general sense that did not provide any details as to how a concept such as student-led learning would be different when learning and teaching engineering compared to any other subject. Broad, general comments such as these continued as the discussion progressed to how the participants might get their future students to Engineering Town.

Providing encouragement for pursuing engineering. While participants felt that their future students could make it to Engineering Town, few could provide specific steps that they could take as the teacher to encourage their students to learn about engineering. Participants commonly responded that they would get their students to Engineering Town by “encouraging” them or “exposing” them to engineering. When asked to explain what “encouragement” or “exposure” would look like in their classroom, participants experienced difficulty in providing specific details. This tendency was well represented across five of the six focus groups with twenty-eight total comments, including:

“I want to provide them with experiences.”
“Its giving them the support and, like I said, asking those questions is a big thing to get them thinking in that kind of a way and just giving them the opportunities to kind of, try stuff and experiment and all that.”

“Encourage”

“Motivate”

“I don’t know, I encourage them to follow their dreams, do whatever they want to do.”

“Showing that it is an option.”

“Exposing them to it and getting them those opportunities.”

These data show that participants were unsure of how they as a teacher were going to get their future students engaged in engineering. However, they did recognize that science, technology, and mathematics could be used as entry points for engineering instruction.

**Integrating STEM content.** Discussions on how to teach engineering and engineering’s relationship to the other STEM subjects led to participants discussing the concept of STEM integration. Data from four focus groups and twenty-four journal entries indicated that participants viewed content integration as a realistic approach to incorporating engineering in the K-12 elementary classroom.

“I can see it being used throughout the year. It needs to be integrated throughout the year I would say.”

“I was thinking it’d be easier to like integrate them with other standards.”

I feel like it’s a great way to tie everything together, like tie your math lesson and your science lesson and you know now at the end of the week we’re going to take what you learned and we’re going to make this and it’s a good way for the students to apply it.”

“You know you put engineering up and every time you do a math lesson or every time you do a science lesson you take ten minutes at the end and say how does this apply to engineering?”
The journal entries that participants completed provided further insight into how participants conceptualized the integration of STEM subjects. As part of the journal entry, participants were asked to specifically describe what they thought qualified engineering as a separate and distinct subject area in education. Overall, participants indicated that they perceived engineering as the sum of science, math, and technology. This trend was clearly present in the journal entries (16 entries) and focus group discussions (9 comments from four focus groups). If participants did not view engineering as the sum of the remaining STEM subjects, they often viewed it as an equivalent to science. Statements on engineering’s relationship to the other STEM subjects included:

“I see it as, like, engineering as like science, math, and technology all combined kind of, because it is using all three of those things I guess?”

“I believe that since engineering includes all three subject areas, it is required be its own subject.”

“I think engineering separates itself from the other subjects because it combines all of them.”

“Engineering is also a way to apply the three areas of science, math and technology into one.”

“Engineering is a science that involves creating or improving an idea or physical object.”

“To me, engineering is the process of using sciences to construct things.”

**Needs for teaching engineering.** Finally, as participants discussed teaching engineering in their future elementary classrooms they commented on what they perceived as necessary if they were to teach engineering successfully. Participants provided few specific details on what would help prepare them for K-12 engineering education, but some common
patterns did emerge. Participants in four focus groups indicated that learning more about content integration would be beneficial:

“…how to extract the math and the science from an activity like this.”

“…how to integrate two subject areas, like the math and the science together, so you’re not just having like your students work on ‘Ok, now we’re going to do science for 30 minutes and then we’re going to turn over and do math for an hour.’ You can do both together for an hour and half.”

“I would have then wanted them to teach me how that applies to the classroom, like how engineering can apply to science and technology and math and I could put that in a classroom. And, you know, why something like this is important for kids to learn. You know, why you would do that, not just cause its fun.”

Two focus groups built upon this idea of content integration and discussed the idea of a STEM methods course that would teach them how to integrate engineering into the other STEM subjects. Participants who discussed this idea felt that a methods course that taught them how to integrate the STEM subjects would be more beneficial than a separate engineering methods course:

“…or something at the end, to tie all of it together. Maybe not as in depth as what we currently do in the math and science and tech, but something at the end just to tie them all together.”

“It’d just be helpful to practice I think. Maybe not an engineering course, but an integration course?”

“My idea would be to have one big STEM methods class, and just bring them all together and show you how you can integrate all those subjects into one.”

Participants also stated that if they were to teach engineering in their classrooms, they would want several examples of activities students could do along with other resources such as lesson planning materials, other experienced teachers, and time to practice.
Summary of Perceptions Regarding K-12 Engineering Education

Preservice elementary teachers felt that their future students would be able to succeed in engineering. The notion that young students are more capable of doing engineering due to their experience with technology also influenced participants’ perceptions of students’ likelihood of success in engineering. As participants envisioned students in an engineering classroom, they stated that students would be working independently with little guidance from the teacher.

Participants envisioned themselves having a minimal role in an engineering classroom. Some participants stated that they would just observe while others stated that they would use questioning and discussion facilitation to guide students. The culture of an engineering classroom was described as hands-on, student-led, and mistake friendly. When asked how they would encourage students to pursue engineering, participants provided vague and brief comments indicating that they were unsure. Participants did recognize science, math, and technology as entry points for engineering instruction and discussed the importance of content integration. Finally, the participants stated that they needed to know more about how to integrate subjects in addition to resources, lesson plans, other experienced teachers, and time if they were to learn to teach engineering.

Research Question 3: To What Extent are Preservice Elementary Teachers Receptive to K-12 Engineering Education?

In this study, receptivity was operationalized using a scale (See Table 11). More receptive participants’ were defined as those willing to share their personal emotions with regards to K-12 engineering education. In addition, more receptive participants were defined as those who displayed positive dispositions toward engineering education. Less receptive
participants were defined as those who shared personal emotions and negative dispositions. This included disregarding or rejecting the idea of K-12 engineering education as demonstrated by the tone and content of comments. Those who did not express their personal emotions and redirected the question to tangential issues occupied the area between more and less receptive. The data indicated that these participants were closer to less receptive than more receptive, yet not meeting the definition of less receptive.

Table 12

Scale of Receptivity

<table>
<thead>
<tr>
<th>Degree of Receptivity</th>
<th>Indicators</th>
</tr>
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<tbody>
<tr>
<td>More Receptive</td>
<td>1. Willing to express personal emotions and positive disposition.</td>
</tr>
<tr>
<td></td>
<td>2. Little to no verbal expression of personal emotions and emphasis on tangential issues.</td>
</tr>
<tr>
<td>Less Receptive</td>
<td>3. Willing to express personal emotions and negative disposition.</td>
</tr>
</tbody>
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Determining participants’ receptivity towards K-12 engineering education involved taking into consideration the emotional component of their perceptions. This included not only determining the emotions participants felt, but also their willingness to share these emotions. The identification of participants’ emotions towards K-12 engineering education was relevant due to the influence of emotions on how people think (and their subsequent actions). According to Minsky (2003), changing emotional states can result in different ways of thinking. Therefore the different emotions that participants felt towards themselves,
students, and other factors while discussing K-12 engineering education resulted in varying degrees of receptivity towards the topic.

There are several emotional states that can be associated with receptivity. For example, a highly receptive participant would express excitement, enthusiasm, and energy while a participant with extremely low receptivity would be withdrawn, anxious, or perhaps even angry. In addition, several emotional states exist between these two extremes. Optimism, apprehension, pessimism, and fear are emotional states between high receptivity and low receptivity. The participants in this study commonly expressed these in-between emotional states when discussing their receptivity to engineering education.

The research question “To what extent are preservice elementary teachers receptive to K-12 engineering education?” was answered using participants’ responses to questions during the focus group discussions. Specifically, participants were asked questions such as:

- “How do you feel about using teaching methods that include engineering design in your classroom?”
- “How important do you think it is that your future students have an understanding of engineering?”
- “How viable do you think K-12 engineering education is?”

These questions were designed to capture the personal attitudes and feelings of the participants regarding K-12 engineering education. Of all the questions asked during the focus groups, participants spent the most time providing responses to these questions. On average, 20% (8 min. 45 sec.) of the discussion time in each focus group was spent on attitudes towards engineering (See Table 9). The content analysis of these discussions distilled three common emotional states across the focus groups that indicated how receptive
preservice elementary teachers were to K-12 engineering education: apprehension, fear, and optimism.

**Overview of Findings**

The tone of the discussions about engineering education followed a similar pattern across focus groups. Some participants openly expressed their feelings without being pressured. It became apparent as these discussions began that some participants felt they should provide positive responses regardless of their personal feelings. However, once one participant shared their authentic personal feelings this often led to other participants doing the same. There would occasionally be periods of silence that were broken only after further coaxing. While participants may have been talking over each other during previous questions, this occurred less frequently during these discussions. While some participants were okay with their own uneasiness, others were not. Those who were not tended to become quiet and respond sparingly. Overall the tone was somewhat quieter as compared to other parts of the discussions.

Participants expressed three emotional states during this study: apprehensive but optimistic, fearful and pessimistic, and pessimistic due to apprehension (See Figure 3). The most common emotional response was apprehensive but optimistic. Participants were apprehensive and this apprehension stemmed from their own perceived lack of ability. However, despite their apprehension these participants viewed engineering education positively. Other participants indicated that they were less receptive by expressing fear and pessimism. This emotional state was less common than apprehension, with five focus groups (coded thirteen times) containing participants who found the notion of K-12 engineering education “scary”, primarily due to their aversion to science and mathematics.
Figure 3. Preservice Elementary Teachers’ Engineering Education Receptivity Patterns as They Correlate to the Receptivity Scale.

While some participants indicated their apprehension toward K-12 engineering education by sharing their own personal feelings on the matter, other participants indicated apprehension and moderate receptivity by reluctantly sharing personal feelings and attempting to redirect the question by focusing on K-12 engineering education’s absence from standardized tests.

The apprehension and fear that participants expressed originated from three issues: their lack of confidence in their math and science content knowledge, their lack of confidence in their engineering content knowledge, and their lack of confidence in their ability to teach engineering. These issues were directly expressed in the comments that were provided by participants. The rest of this section is organized according to the three predominant emotional states that participants expressed: apprehensive but optimistic, fearful
and pessimistic, and pessimistic due to apprehension. A complete reporting of these results appears below.

**Apprehensive but Optimistic**

All of the focus groups contained participants who indicated that they felt apprehensive about engineering in the elementary classroom but were open to the idea of including it in their future classrooms. Apprehension was coded nineteen times across the focus groups while optimism was coded twenty-one times. This apprehension stemmed largely from participants not feeling prepared and not knowing enough about engineering content and pedagogy to teach it. These participants were still receptive to the idea of engineering in the elementary classroom, but they recognized that they may not be ready to teach using engineering content and pedagogy. Participants made statements such as:

“It would be beneficial but I just don’t know how to do that. I just don’t know what would be like age appropriate like experiments to do. I can learn real easy, I just don’t know.”

“It makes me nervous because I don’t really know anything about engineering. I’ve never been involved with it to like know how to teach it or like concepts about it or what it really is, just the general idea of it.”

“It kind of makes me, just because of my experience in the past, it almost makes me uncomfortable because that’s not what I’m used to, that’s not what I went through. So it would take a lot of getting used to, but I feel like it is worth it to be put in that position as a teacher.”

“It’s also, if [engineering lessons] don’t go exactly the way you think there supposed to, you could really quickly, easily lose control of what is going on. I think that piece of it makes me a little bit nervous, is it not going perfect or maybe not the best lesson plan or not the most efficient way for the kids to get it done, and then everything could snowball. That makes me nervous but it still seems worth the risk.”

“I am kind of scared of just, the engineering concept too and I think even with my own, like, I don’t know…apprehension, it’s still something that obviously needs to be taught.”
In statements such as these the participants acknowledged their own limitations with regards to their ability to teach engineering. While apprehensive, these participants also stated that they felt engineering would be very engaging for students, increase students’ problem solving capabilities, strengthen the connections between the STEM subjects, and could make teaching more fulfilling. The emotion of optimism was coded based upon whether comments were centered on the participants as teachers or their future students. Participants in six focus groups provided twenty-one optimistic comments on K-12 engineering that focused on their roles as teachers. Additionally, four focus groups provided twelve optimistic comments that focused on students. The following provides some examples of optimistic comments that participants made regarding themselves as teachers:

“IT’s a little bit more exciting than just…writing math problems.”

“It’s engaging instead of sitting there and letting someone else do the work, it’s engaging. They actually want to participate.”

“I think it’s something teachers can get excited about.”

“Well I think it’s great…there’s no problem solving [anymore] and I think this would bring it back.”

“I think it’s more fun to teach that way, like to have that freedom. I like watching discoveries that the kids make and I like that ‘eureka’ moment, so I think it would be much more fulfilling to have an environment that focused more engineering based than memorize this and regurgitate it and we’re moving on.”

“I feel like it would be more fulfilling for me to see my students learn, not on their own because you’re obviously the teacher, but like, discovering things on their own and putting things, like making connections between things.”

**Fearful and Pessimistic**

A smaller number of participants provided responses that indicated they were not receptive to the idea of elementary engineering education or taking an engineering methods
course. The most prominent reason behind their negative views was fear. This emotion was coded thirteen times in five of the six focus group discussions. Their fear and pessimism was often based upon their aversion to math and science. These participants recognized that teaching engineering in the elementary classroom would require both mathematical and scientific concepts. These connections to math and science made engineering education unappealing. Other participants were fearful and pessimistic because of their lack of engineering knowledge. Statements that expressed these feelings include the following:

“Cause when I hear the term engineering, I’m scared. It’s like math.”

“I mean I don’t really want to do it. It sounds like really hard.”

“I think even if we were like given like the option to take an engineering class I think a lot of us would be like scared because I know me personally, when I hear like engineering stuff I’m just like...I would be scared to death because math is just sometimes can be scary. I don’t know…like engineering I guess would be like a weird thing for us to do.”

“It kind of scares me just because I have like no background with engineering. Like I don’t really, and science and math aren’t my forte, my favorite thing. So personally knowing that I would have to teach like engineering would scare me…”

“Yeah I would feel unqualified to teach it. I hate science with a passion. I have never been good at it. I have never enjoyed it my entire life so I wouldn’t be your prime candidate to I mean…hands on experience isn’t all that, like once in awhile it would be like a great way to involve kids in like a harder subject but I have no passion for science and so I would not feel comfortable teaching from an engineering standpoint.”

These participants did not necessarily reject the idea of elementary engineering education, but they did state that they did not want to be the teachers responsible for teaching it. Participants’ past experiences with science and math and their perceptions of their own abilities in these two subjects led to low receptivity.
The number of comments coded as optimistic (21), apprehensive (19), and fearful (13) indicated that most of the forty-four participants were willing to share their personal emotions and feelings regarding K-12 engineering education. These emotions were a focal point of most focus group discussions when talking about how they felt about K-12 engineering education. Participants based their receptivity largely upon how they perceived their own understandings of, comfort level with, and affinity for engineering, math, and science as well as their own teaching abilities. Whether they expressed positivity or negativity towards engineering education, these participants recognized that they would need to change themselves if they were to teach engineering. However, four of the six focus groups contained participants who were reluctant to share how they felt and chose to redirect questions away from themselves. While less common, this technique was interpreted as apprehension in that participants were unwilling to admit their own feelings toward K-12 engineering education.

**Pessimism Due to Apprehension**

When asked the question “How do you feel about using teaching methods that include engineering design in your classroom?” the goal was to get participants talking about themselves and how they felt about teaching engineering in their future classrooms. While most participants stated their emotions of apprehension, optimism, or fear directly, other participants indirectly expressed their feelings of apprehension (Figure 3). These participants felt the apprehension similar to those who were apprehensive but optimistic. However, instead of being tempered by optimism, the apprehension these participants felt was tempered with pessimism.
This pessimism concerned the difficulties associated with assessing engineering learning and its absence from standardized tests. From the focus group discussions, twelve comments were coded “difficulty with assessment.” This emotional state was less common in that it had fewer comments and was coded in only four of the six focus groups. These participants claimed that engineering in the elementary classroom was unrealistic in an education system dominated by subjects that are assessed at the state and federal levels via standardized tests. Participants who expressed this claim indicated that they were closer to the less receptive end of the receptivity scale regarding K-12 engineering education (Table 11). Instead of sharing their personal emotions, these participants emphasized the obstacle of standardized testing. By providing pessimistic comments on an issue that was not under their control, participants could express receptivity without having to admit their own feelings of apprehension. Simply put, the comments provided by these participants indicated that they were not interested in teaching engineering. Stating such a sentiment would have reflected upon them, so instead they provided a reason beyond themselves that they used to invalidate K-12 engineering education. Statements regarding this issue include:

“I’m nervous because the exams that the state sends out, it’s not like you construct this, it’s A, B, C, D, like which one is it. That’s like you know what the principal in a school district wants all your kids to master you know. You need to get those scores in you know, to get funds and I mean I love this because I feel like it’d be very hands on but I’m just nervous of like assessment…”

“I think [engineering] won’t be taught until the standardized tests that kids have to take reflect that, until there are design questions in it where you are actually getting to a design problem. Until our testing reflects that, what’s the point of teaching it when you have to meet all these other standards?”

“It’s [K-12 engineering] such a new practice that it’s not widely used in all of the schools, so it’s not something that we have to know how to do I guess right now because like the federal government…or the Iowa government [doesn’t think so].
“I mean we’re saying that this engineering thing is a great thing and the negative part of it is you know how do we test that and that’s just like a whole other issue that needs worked out.”

“…because [engineering] is not tested by the federal government right now.”

It is possible that these participants truly felt that only teaching the subjects that are recognized by the state and federal government was necessary or acceptable, regardless of their own personal feelings. However, answering a question that was directed at their own personal feelings by commenting on the limitations imposed by standardized testing was interpreted as being closer to the less receptive end of the scale representing K-12 engineering education receptivity (Table 11). If this was the case, the standardized testing argument was simply a way to justify participants’ own lack of receptivity.

**Summary of Participants’ Receptivity**

The responses provided by participants indicated that, as a whole, engineering education was viewed with apprehension and that participants felt unprepared or unqualified to teach engineering. However, for a majority of the preservice elementary teachers this apprehension was tempered by optimism. Along with their apprehension, participants were receptive to the idea of teaching engineering in their future elementary classrooms. This pattern was common in all six focus groups. Five of the six focus groups also contained participants who were not only apprehensive but also fearful of the idea of including engineering as a subject in their classrooms. The fear that participants shared was due primarily to their fear of math and science. These preservice elementary teachers were fearful and pessimistic.

The apprehension that participants felt led some of them to be reluctant when sharing their feelings. These participants redirected the question about their feelings by focusing on
standardized testing. They viewed K-12 engineering education as unrealistic due to the emphasis that schools place on subjects that are assessed by state and federal tests. This pessimistic portrayal was an indication that these participants felt apprehensive but were unwilling to let their personal feelings be the source of their abated receptivity. Providing a reason why K-12 engineering education could not be done was easier and less damaging to their self-image than simply stating they did not want to be responsible for teaching it.

**Chapter Summary**

This chapter presented the results of this qualitative investigation of preservice elementary teachers’ perceptions of engineering and their receptivity towards K-12 engineering education. Triangulation of the researcher observations, video recordings, and focus group discussions illuminated how the preservice elementary teachers approached an engineering design task. The preservice teachers’ approaches emerged in two patterns: recognition of relevant engineering design factors and issues of concern related to engineering design. The most salient finding from the engineering design task was that the preservice elementary teachers did not utilize any deliberate design process when engaged in a design task.

The definitions that preservice elementary teachers provided for engineering indicated that they perceived engineering as a profession responsible for the construction of products. If participants could not provide a definition for engineering they listed types of engineering. Regarding the methods used by engineering, participants stated that trial and error is how engineering is done.

Preservice elementary teachers felt that their future students would be able to succeed in engineering. As participants envisioned students in an engineering classroom, they stated
that students would be working independently. Participants envisioned themselves having a minimal role in an engineering classroom. Some participants stated that they would just observe while others stated that they would use questioning and discussion facilitation to guide students. When asked how they would encourage students to pursue engineering, participants provided vague and brief comments indicating that they were unsure. Participants did recognize science, math, and technology as entry points for engineering instruction and discussed the importance of content integration.

Participants indicated that, as a whole, engineering education was viewed with apprehension and that participants felt unprepared or unqualified to teach engineering. For a majority of the preservice elementary teachers this apprehension was tempered by optimism. Along with their apprehension, participants were receptive to the idea of teaching engineering in their future elementary classrooms. Other participants were apprehensive but also fearful of the idea of including engineering as a subject in their classrooms. The fear that participants shared was due primarily to their fear of math and science. These preservice elementary teachers were fearful and pessimistic. Another set of participants claimed that K-12 engineering education was unrealistic in an education system dominated by subjects that are assessed by standardized tests. Participants who expressed this claim indicated that they were closer to the less receptive end of the receptivity scale regarding K-12 engineering education.
CHAPTER 5. DISCUSSION

The purpose of this exploratory, qualitative study was to investigate preservice elementary teachers’ perceptions of and receptivity towards engineering and K-12 engineering education. The literature review indicated that few studies had been conducted that examined preservice elementary teachers’ understandings of engineering. This study added to the knowledge base about preservice elementary teachers’ perceptions and supported findings from previous research studies.

The purpose of this chapter is to discuss the significance of the major findings from this study as they relate to the research literature and to offer recommendations for future research and development. Three significant findings from this study are discussed in this chapter:

1. Preservice elementary teachers’ perceptions of engineering as articulated in their definitions of the discipline.
2. The use of an authentic design task to identify preservice elementary teachers’ formative understandings of engineering and engineering design.
3. Preservice elementary teachers’ receptivity to K-12 engineering education.

The chapter begins with a discussion on how perceptions have been approached in previous studies on engineering education and in this study.

Perceptions of Engineering

According to Calderhead (1996), perceptions can be connected to how a teacher views learners and learning, teaching, subject matter, learning to teach, and themselves as a teacher. The work of Calderhead (1996) and Minsky (2003) highlights the far-reaching impact of perceptions and also suggests that researchers can approach the study and impact
of perceptions in varying ways. Previous research in this area examined perceptions of engineering subject matter (e.g. definitions of engineering) (ASEE, 2006; Davis & Gibbin, 2002; Lambert, Diefes-Dux, Beck, Duncan, Oware, and Nemeth, 2007; NAE, 2008) and perceptions of teaching engineering (ASEE, 2005; Baker, Yasar-Purzer, Kurpius, Krause, and Roberts, 2007; Gallagher, 2004; Hudson, English, and Dawes, 2009; Yasar, Baker, Robinson-Kurpius, Krause and Roberts, 2006).

When asked to define engineering, the preservice elementary teachers in this study frequently provided statements such as “building and constructing things,” and “designing and constructing machines.” This finding is consistent with the research literature about educators’ and the general public’s definitions of engineering. Definitions provided by the general public strongly associated engineering with building or constructing machinery (Davis & Gibson, 2002; NAE, 2008). Inservice teachers were found to also describe engineering as the construction of structures or products (ASEE, 2006; Lambert et al., 2007). The preservice teachers in Gallager’s (2004) study also described engineering as building, creating, designing, and inventing.

The definitions of engineering from the current study as well as previous studies were the result of asking participants questions such as “What is engineering?” and “What do engineers do?” (ASEE, 2006; Davis & Gibson, 2002; Gallagher, 2004; Lambert et al., 2007; NAE, 2008). This approach has yielded data regarding participants’ inert knowledge of engineering. However, previous work in this area did not yield insight into educators’ perceptions and understanding of how engineering is done. This study offers information regarding preservice elementary teachers’ inert and active knowledge about how engineering is done. That is, responses regarding how engineering is done indicated that participants
could only express some ideas while other ideas could be both expressed and applied. In addition, the current study used an authentic engineering design task from which to generate participants’ knowledge and understanding of engineering and engineering design.

Preservice Elementary Teachers’ Approach to Engineering Design

Several studies in the research literature investigated ways to shape inservice and preservice teachers’ perceptions of engineering design. Lambert et al. (2007) examined the effects of inservice teachers’ participation in a week-long engineering academy, and Baker et al. (2007) investigated the effects of a graduate level engineering design course on inservice teachers’ perceptions of teaching design, engineering, and technology. With regards to preservice teachers, researchers have investigated how engineering workshops (Hudson et al., 2009) and an engineering course (Gallagher, 2004) shaped perceptions of teaching engineering in an elementary classroom.

Unlike this previous research, this study engaged preservice elementary teachers in an authentic engineering design task with no prior direct instruction. This provided data about preservice elementary teachers’ initial, formative understandings and perceptions of how engineering is done and how they might teach engineering in the classroom. The distinction between the formative perceptions gained as a result of this study and the summative perceptions examined in past studies is important. The work of Posner, Strike, Hewson, and Gertzog (1982) regarding conceptual change provides a solid basis for the importance of preconceptions in science learning. Their findings also apply to engineering learning. Posner et al. (1982) state that “epistemological commitments” (p. 224) are the foundation for how decisions are made regarding new knowledge. If preservice elementary teachers are expected
to learn about engineering and engineering design and do not possess the “epistemological commitments” regarding engineering that are required for rational conceptual change, then they are forced to alter their concepts of engineering on an irrational basis. Posner et al. (1982) compares this to students accepting theory because the book or instructor says it is “true.”

The current study provided formative information about preservice elementary teachers existing or pre-instructional conceptions of engineering. The results of this work could be used to pinpoint the “epistemological commitments” that preservice elementary possess regarding engineering design. In other words, the engineering design task in this study served as a way to operationalize the understanding, or lack thereof, that preservice elementary teachers already possessed with regards to engineering design prior to instruction. Knowing that preservice elementary teachers perceive engineering design as primarily trial and error and that they struggle to rationalize their design decisions provides the beginning of a foundation upon which engineering education for preservice educators can be constructed.

**Preservice Elementary Teachers’ Receptivity to K-12 Engineering Education**

In addition to examining the formative understandings that preservice elementary teachers possessed regarding engineering design, this study also provided insight into the perceptions and emotional states that preservice elementary teachers associated with K-12 engineering education. Emotions, their connection to perceptions, and teachers’ receptivity to engineering education were not discussed to a great extent in the literature. The findings of the ASEE (2006) survey indicated that inservice teachers felt confident with their knowledge of engineering. The study conducted by Yasar et al. (2006) also found that inservice teachers felt confident with their perceptions of engineering despite feeling unconfident with concepts
related to engineering. The preservice teachers in the study conducted by Hudson et al. (2009) indicated that they felt “enthusiastic” after completing two engineering workshops. Besides these brief mentions of confidence and enthusiasm, discussion or acknowledgement of emotion as a significant variable in educators’ perceptions and receptivity towards K-12 engineering education was rarely included in the research literature.

In addition to describing the confidence inservice teachers felt about engineering, Yasar et al. (2006) noted that inservice elementary teachers were the least receptive to the idea of teaching engineering content. Yasar et al. (2006) did not provide a specific reason as to why, but the authors hypothesized that the lack of interest may have been due to elementary teachers being content generalists mostly interested in children as compared to middle and high school teachers who were seen as content specialists mostly interested in science. This hypothesis claims that the receptivity of elementary teachers was due to the nature of their teaching position. In contrast, the data from this study indicated that receptivity has much to do with the emotions that preservice elementary teachers feel towards engineering education and how these emotions connect to the perceptions they possess regarding engineering and themselves as teachers of engineering.

According to Minsky (2003), a shift in emotional states results in shifting to a different way of thinking. This means it is possible for two individuals to objectively understand a concept in a similar way but subjectively perceive the concept differently based upon how the concept makes them feel. In this study, participants objectively understood engineering in similar ways but varied with regards to their subjective perceptions due in part to how engineering (and related concepts) made them feel.
Unlike the inservice teachers in previous studies (ASEE, 2006; Yasar et al., 2006; Hudson et al., 2009) who expressed confidence or enthusiasm regarding perceptions of engineering, the preservice elementary teachers in this study were aware that they lacked knowledge and skills related to engineering. This perception led to the manifestation of different emotions, which in turn led to different levels of receptiveness towards K-12 engineering education.

The results of this study showed that the preservice elementary teachers experienced three emotional states: apprehensive but optimistic, pessimistic due to apprehension, and fearful and pessimistic. Preservice teachers who felt apprehensive but optimistic viewed K-12 engineering education as an opportunity. In contrast, preservice elementary teachers who expressed fear and pessimism viewed K-12 engineering education as something to be avoided. The low receptivity of these participants creates a barrier that may prevent them from effectively learning how to teach engineering and have a potentially negative impact on their students' learning and perceptions of engineering. The data suggested that the source of these fearful and pessimistic emotions often lied with past experiences in science and math. Further research is needed to understand the depth, strength, and origin of these emotions.

Preservice elementary teachers who were closer to the less receptive end of the receptivity scale felt engineering education was unrealistic due to their perception that standardized tests dictate which subjects are taught in the elementary classroom. The tendency to not directly express their personal emotions and cite tangential factors was interpreted as being pessimistic due to feeling apprehensive. The integration of engineering into the National Science Education Standards (NRC, 2011) and the addition of a technology and engineering component to the 2014 National Assessment of Educational Progress
(National Center for Education Statistics, 2012) theoretically eliminates this rationale. Additional research is needed to more fully understand the nature as well as the depth, strength, and origins of this emotion. Such research can lead to the design of instruction that facilitates preservice elementary teachers’ conceptual and perceptual change about K-12 engineering education.

**Need for Further Research**

The results of this study cannot be considered conclusive. While this study adds to the research literature regarding preservice elementary teachers’ perceptions of K-12 students as learners of engineering, learning to teach engineering, and themselves as teachers of engineering, this new knowledge must be confirmed and expanded upon by subsequent research studies.

According to Frey and Fontana (1993), an exploratory qualitative study such as this is useful for understanding social contexts that are unfamiliar, testing the feasibility of a more complex study, or adding precision to a research problem. The data gained from this study could provide a starting point for research aimed at gathering more generalizable information regarding preservice elementary teachers' knowledge, perceptions and receptiveness regarding K-12 engineering education. Thus, this qualitative study provides a foundation for developing future studies.

**Conclusion**

The American Society for Engineering Education (ASEE) states that “though people spend 95% of their time interacting with the human-made world, few can articulate how our designed world came to be and how the products that we have developed to meet our needs function” (ASEE, 2006). This sentiment expresses a concern that the current education
system in the U.S. fails to provide K-12 students with the opportunities that may lead them to choose engineering as a career or, at the very least, a better understanding and appreciation of the field. Incorporating engineering into K-12 engineering education provides an opportunity to increase students’ understanding of the designed world and the relationships that exist between science, technology, engineering, and mathematics. According to Katehi, Pearson, and Feder (2008) this is a need recognized by the National Science Board, the U.S. Department of Education, the American Association for the Advancement of Science, the National Academies, and several more organizations. In addition, the Next Generation Science Standards (NGSS) give engineering a much more prominent role (NGSS, 2012) and the 2014 National Assessment of Educational Progress will include a technology and engineering component (National Center for Education Statistics, 2012).

Teachers are critical to the effective implementation of engineering curricula at the K-12 level. The identification and exploration of preservice elementary teachers’ perceptions regarding K-12 engineering education is critical as engineering education continues to evolve in the K-12 school system. Examining these perceptions provides a way to make explicit their formative understandings and factors that may impact their receptivity to engineering education. Finally, such research may provide a way forward as scholars and organizations continue to investigate how engineering can be effectively incorporated into K-12 schools.
APPENDIX A. ITEEA STANDARDS 8-13 FOR TECHNOLOGICAL LITERACY

Standard 8. Students will develop an understanding of the attributes of design.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Benchmarks</th>
</tr>
</thead>
</table>
| K-2         | A. Everyone can design solutions to a problem.  
B. Design is a creative process.  
| 3-5         | C. The design process is a purposeful method of planning practical solutions to problems.  
D. Requirements for a design include such factors as the desired elements and features of a product or system or the limits that are placed on the design. |
| 6-8         | E. Design is a creative planning process that leads to useful products and systems.  
F. There is no perfect design.  
G. Requirements for design are made up of criteria and constraints. |
| 9-12        | H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.  
I. Design problems are seldom presented in a clearly defined form.  
J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.  
K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other. |

Standard 9. Students will develop an understanding of engineering design.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Benchmarks</th>
</tr>
</thead>
</table>
| K-2         | A. The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.  
B. Expressing ideas to others verbally and through sketches and models is an important part of the design process. |
| 3-5         | C. The engineering design process involves defining a problem, generating ideas, selecting a solution, testing the solution(s), making the item, evaluating it, and presenting the results.  
D. When designing an object, it is important to be creative and consider all ideas.  
E. Models are used to communicate and test design ideas and processes. |
| 6-8         | F. Design involves a set of steps, which can be performed in different sequences and repeated as needed.  
G. Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.  
H. Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions. |
| 9-12        | I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.  
J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.  
K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.  
L. The process of engineering design takes into account a number of factors. |
Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-2</td>
<td>A. Asking questions and making observations helps a person to figure out how things work.</td>
</tr>
<tr>
<td></td>
<td>B. All products and systems are subject to failure. Many products and systems, however, can be fixed.</td>
</tr>
<tr>
<td>3-5</td>
<td>C. Troubleshooting is a way of finding out why something does not work so that it can be fixed.</td>
</tr>
<tr>
<td></td>
<td>D. Invention and innovation are creative ways to turn ideas into real things.</td>
</tr>
<tr>
<td></td>
<td>E. The process of experimentation, which is common in science, can also be used to solve technological problems.</td>
</tr>
<tr>
<td>6-8</td>
<td>F. Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system.</td>
</tr>
<tr>
<td></td>
<td>G. Invention is the process of turning ideas and imagination into devices and systems. Innovation is the process of modifying an existing product or system to improve it.</td>
</tr>
<tr>
<td></td>
<td>H. Some technological problems are best solved through experimentation.</td>
</tr>
<tr>
<td>9-12</td>
<td>I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.</td>
</tr>
<tr>
<td></td>
<td>J. Technological problems must be researched before they can be solved.</td>
</tr>
<tr>
<td></td>
<td>K. Not all problems are technological, and not every problem can be solved using technology.</td>
</tr>
<tr>
<td></td>
<td>L. Many technological problems require a multidisciplinary approach.</td>
</tr>
</tbody>
</table>

Standard 11. Students will develop the abilities to apply the design process.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>As part of learning how to apply design processes, students should learn that:</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-2</td>
<td>A. Brainstorm people’s needs and wants and pick some problems that can be solved through the design process.</td>
</tr>
<tr>
<td></td>
<td>B. Build or construct an object using the design process.</td>
</tr>
<tr>
<td></td>
<td>C. Investigate how things are made and how they can be improved.</td>
</tr>
<tr>
<td>3-5</td>
<td>D. Identify and collect information about everyday problems that can be solved by technology, and generate ideas and requirements for solving a problem.</td>
</tr>
<tr>
<td></td>
<td>E. The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.</td>
</tr>
<tr>
<td></td>
<td>F. Test and evaluate the solutions for the design problem.</td>
</tr>
<tr>
<td></td>
<td>G. Improve the design solutions.</td>
</tr>
<tr>
<td>6-8</td>
<td>H. Apply a design process to solve problems in and beyond the laboratory-classroom.</td>
</tr>
<tr>
<td></td>
<td>I. Specify criteria and constraints for the design.</td>
</tr>
<tr>
<td></td>
<td>J. Make two-dimensional and three-dimensional representations of the designed solution.</td>
</tr>
<tr>
<td></td>
<td>K. Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints, and refine as needed.</td>
</tr>
<tr>
<td></td>
<td>L. Make a product or system and document the solution.</td>
</tr>
<tr>
<td>9-12</td>
<td>M. Identify the design problem to solve and decide whether or not to address it.</td>
</tr>
<tr>
<td></td>
<td>N. Identify criteria and constraints and determine how these will affect the design process.</td>
</tr>
<tr>
<td></td>
<td>O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.</td>
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<tr>
<td></td>
<td>P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.</td>
</tr>
<tr>
<td></td>
<td>Q. Develop and produce a product or system using a design process.</td>
</tr>
<tr>
<td></td>
<td>R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.</td>
</tr>
</tbody>
</table>
**Standard 12.** Students will develop the abilities to use and maintain technological products and systems.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-12</td>
<td>As part of learning how to use and maintain technological products and systems, students should learn that:</td>
</tr>
<tr>
<td></td>
<td>A. Discover how things work.</td>
</tr>
<tr>
<td></td>
<td>B. Use hand tools correctly and safely and be able to name them correctly.</td>
</tr>
<tr>
<td></td>
<td>C. Recognize and use everyday symbols.</td>
</tr>
<tr>
<td>3-5</td>
<td>D. Follow step-by-step directions to assemble a product.</td>
</tr>
<tr>
<td></td>
<td>E. Select and safely use tools, products, and systems for specific tasks.</td>
</tr>
<tr>
<td></td>
<td>F. Use computers to access and organize information.</td>
</tr>
<tr>
<td></td>
<td>G. Use common symbols, such as numbers and words, to communicate key ideas.</td>
</tr>
<tr>
<td>6-8</td>
<td>H. Use information provided in manuals, protocols, or by experienced people to see and understand how things work.</td>
</tr>
<tr>
<td></td>
<td>I. Use tools, materials, and machines safely to diagnose, adjust, and repair systems.</td>
</tr>
<tr>
<td></td>
<td>J. Use computers and calculators in various applications.</td>
</tr>
<tr>
<td>9-12</td>
<td>K. Operate and maintain systems in order to achieve a given purpose.</td>
</tr>
<tr>
<td></td>
<td>L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.</td>
</tr>
<tr>
<td></td>
<td>M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.</td>
</tr>
<tr>
<td></td>
<td>N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.</td>
</tr>
<tr>
<td></td>
<td>O. Operate systems so that they function in the way they were designed.</td>
</tr>
<tr>
<td></td>
<td>P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.</td>
</tr>
</tbody>
</table>

**Standard 13.** Students will develop the abilities to assess the impact of products and systems.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-12</td>
<td>As part of learning how to assess the impact of products and systems, students should learn that:</td>
</tr>
<tr>
<td></td>
<td>A. Collect information about everyday products and systems by asking questions.</td>
</tr>
<tr>
<td></td>
<td>B. Determine if the human use of a product or system creates positive or negative results.</td>
</tr>
<tr>
<td>3-5</td>
<td>C. Compare, contrast, and classify collected information in order to identify patterns.</td>
</tr>
<tr>
<td></td>
<td>D. Investigate and assess the influence of a specific technology on the individual, family, community, and environment.</td>
</tr>
<tr>
<td></td>
<td>E. Examine the trade-offs of using a product or system and decide when it could be used.</td>
</tr>
<tr>
<td>6-8</td>
<td>F. Design and use instruments to gather data.</td>
</tr>
<tr>
<td></td>
<td>G. Use data collected to analyze and interpret trends in order to identify the positive and negative effects of a technology.</td>
</tr>
<tr>
<td></td>
<td>H. Identify trends and monitor potential consequences of technological development.</td>
</tr>
<tr>
<td></td>
<td>I. Interpret and evaluate the accuracy of the information obtained and determine if it is useful.</td>
</tr>
<tr>
<td>9-12</td>
<td>J. Collect information and evaluate its quality.</td>
</tr>
<tr>
<td></td>
<td>K. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and environment.</td>
</tr>
<tr>
<td></td>
<td>L. Use assessment techniques, such as trend analysis and experimentation, to make decisions about the future development of technology.</td>
</tr>
<tr>
<td></td>
<td>M. Design forecasting techniques to evaluate the results of altering natural systems.</td>
</tr>
</tbody>
</table>
APPENDIX B. FOCUS GROUP PROTOCOL AND QUESTIONS

1. Introduction:

Name tags

My name is Dennis Culver and I am a graduate student in education. Today we are going to discuss K-12 engineering education. You were asked to participate in this discussion because you are upper level students in the teacher education program and are enrolled in the science methods course. There will be three parts to our focus group today. First, you will be asked to sign an informed consent document and complete a brief survey. Second, you will be asked to complete a short activity. The third part will be used for discussion and will take most of our time.

There are no right or wrong answers during the activity or the discussion. This is a nonjudgmental and impartial group, so please feel free to openly share your thoughts. All I ask is that you fully participate.

I will be video recording the group during the design activity and audio recording the discussions. All of this information will be kept confidential and your identities will remain anonymous.

What questions do you have? Feel free to ask questions at any time.

2. Informed Consent Documents

3. Demographic Survey

------------------------------------------------------------------------------------------------------------

4. Parachute Activity (20-30 minutes)

For our activity, I would like you imagine that you are on a team that has been employed by a cereal company. This cereal company wants to put a toy parachute in their cereal boxes. It has to be made out of simple materials: coffee filters, string and washers. They want to do this because they think it will help sell more cereal. The company would like the parachute to fall as slowly as possible because they think that will make it more fun. The job of your team is to figure out what affects the way a coffee filter parachute falls, design a coffee filter parachute, and then test your parachute. Your team will then make recommendations to the cereal company on how they should design their parachute.

I’ve created stations with the necessary materials to complete this activity. I am going to split you into teams and have you begin.

5. Transition to discussion. Have everyone return to his or her seats around the table.
6. Discussion (50 minutes)

**Engineering Content**
- How did you go about creating the parachute?
  - What was your process?
- How might the parachute activity be related to engineering?
- Imagine that you want to mass-produce your parachute as a product people would buy. How would this influence or change your parachute design?

**Engineering Context**
- How might the parachute activity be used to teach math and science lessons?
  - How is this different than a typical lesson?
  - What concepts might it emphasize?
- Imagine a classroom that the parachute activity could take place in. What does it look like?
  - What materials and resources are available?
  - How is the classroom arranged?
  - How is it different from a typical classroom?

**Engineering Pedagogy**
- Imagine you are having your future students complete the parachute activity. How might you teach them your design process?
- STEM (science, technology, engineering, mathematics) education has been receiving a large amount of national attention due to its importance. However, as a preservice teacher you take methods courses in science (CI 449), math (CI 448) and technology (CI 201) but not engineering. Why do you think there is no engineering methods course?
  - What do you think you would learn in an engineering teaching methods course?
- How do you feel about using teaching methods that include engineering design in your future elementary classroom?
  - Under what conditions would an engineering pedagogy be suitable?
  - To what extent do you believe a K-6 student is capable of solving an engineering problem using design?

**Engineering Town**
- What does an engineer look like in this town?
  - What are their ways of doing things?
  - What is the culture of the town?
  - Who is not there?
  - Who is there?
How many of your future students will make it to Engineering Town?
- What will be your role in getting your students to Engineering Town?
APPENDIX C. DEMOGRAPHIC SURVEY

1. Which category below includes your age?
   - 18-19
   - 20-21
   - 22-23
   - 24-25
   - 26-27
   - 28-29
   - 30 or older

2. What is your gender?
   - Female
   - Male

3. What is your ethnicity? (Check all that apply.)
   - American Indian
   - Asian or Pacific Islander
   - Latino or Hispanic
   - Alaskan Native
   - Black or African American
   - White

4. In what semester will you student teach?
   - Fall 2012
   - Spring 2013
   - Fall 2013
   - Other (please specify)

5. What is your major(s)?
6. What is your minor? (If you do not have a minor, write "none.")

7. What teaching endorsement(s) are you pursuing? (Check all that apply.)
   - Art
   - English and Language Arts
   - English as a Second Language
   - Health
   - History
   - Mathematics
   - Music
   - Reading
   - Science
   - Social Studies
   - Special Education
   - Speech/Theater
   - World Languages

8. Which of the statements below describe your personal experience with engineering? (Check all that apply.)
   - I have had no real experience with engineering.
   - I have fixed machines around my house, such as the lawnmower, dryer, computer, etc.
   - I have participated in engineering competitions, such as a robotics competition.
   - I have taken engineering courses.
   Other experiences:

9. How much experience have you had with people who are engineers? (Check all that apply.)
   - I have had no experience with an engineer.
   - I know people who are engineers.
   - I am friends with engineers.
   - Someone in my family is an engineer.
   - I was once enrolled as an engineering major.
   Other experiences:

10. Have you taken the Toying with Technology course (CI 570/MSE 570)?
    - Yes
    - No
    - Currently Enrolled
APPENDIX D. DOCUMENTATION OF HUMAN SUBJECTS APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Date: 12/16/2011
To: Dennis Culver
2171 3rd Ave SW
Altoona, IA 50009

CC: Dr. Constance P Hargrave
218 Office and Lab
Dr. EunJin (EJ) Bang
N165D Lagomarcino Hall

From: Office for Responsible Research

Title: Assessing Preservice Elementary Teachers' Knowledge and Perceptions of Engineering

IRB ID: 11-574

Study Review Date: 12/16/2011

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (1) Research conducted in established or commonly accepted education settings involving normal education practices, such as:
  - Research on regular and special education instructional strategies; or
  - Research on the effectiveness of, or the comparison among, instructional techniques, curricula, or classroom management methods.

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

- You do not need to submit an application for annual continuing review.

- You must carry out the research as described in the IRB application. Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.
Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. Only the IRB or designees may make the determination of exemption, even if you conduct a study in the future that is exactly like this study.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.
BIBLIOGRAPHY


