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Leveling the Playing Field: Teacher Perception of Integrated STEM, Engineering, and Engineering Practices

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Leveling the Playing Field: Teacher Perception of Integrated STEM, Engineering, and Engineering Practices

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ABSTRACT

The purpose of this study was to describe the perceptions and approaches of 14 third-through-fifth grade Arkansan elementary teachers towards integrative engineering and engineering practices during 80 hours of integrated STEM professional development training in the summer and fall of 2014. This training was known as Project Flight. The purpose of the professional development was to learn integrated STEM content related to aviation and to write grade level curriculum units using Wiggins and McTighe's Understanding by Design curriculum framework. The current study builds upon on the original research.

Using a mixed method exploratory, embedded QUAL[quan] case study design and a non-experimental convenience sample derived from original 20 participants of Project Flight, this research sought to answer the following question: Does professional development influence elementary teachers' perceptions of the curriculum and instruction of integrated STEM engineering and engineering practices in a 3-to-5 grade level setting? A series of six qualitative and one quantitative sub-questions informed the research of the mixed method question. Hermeneutic content analysis was applied to archival and current qualitative data sets while descriptive statistics, independent *t*-tests, and repeated measures ANOVA tests were performed on the quantitative data. Broad themes in the teachers' perceptions and understanding of the nature of integrated engineering and engineering practices emerged through triangulation.

After the professional development and the teaching of the integrated STEM units, all 14 teachers sustained higher perceptions of personal self-efficacy in their understanding of Next Generation Science Standards (NGSS). The teachers gained understanding of engineering and engineering practices, excluding engineering habits of mind, throughout the professional development training and unit teaching. The research resulted in four major findings specific to

elementary engineering, which included engineering as student social agency and empowerment and the emergence of the engineering design loop as a new heuristic, and three more general non-engineering specific findings. All seven, however, have implications for future elementary engineering professional development as teachers in adopting states start to transition into using the NGSS standards.

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Statement of the Problem

When the Soviets launched Sputnik in 1957, the effect on science education in America was marked. Legislators quickly passed the National Defense Education Act of 1958 ("National defense education act of 1958," 1958) , bringing science fully into K-12 schools and providing monies for vocational teacher training. A few years later, The Elementary and Secondary Education Act (1965) had, as part of its mandate, science and mathematics teacher professional development "as a core strategy to prepare for the nation's students to become first in the world" (Pea & Wojnowski, 2014, p. 9). Today, educational policy in America is responding and reforming science education to address threats of an economic kind by calling for comprehensive federal and state educational reform in support of transitioning from science as an isolated subject towards a K-12 multidisciplinary Science, Technology, Engineering, and Mathematics (STEM) focus (Roehrig, Moore, Wang & Park, 2012).

Along with educational policy and students, teachers and teacher professional development are essential components of any educational reform. Luft and Hewson (2014) , in their meta-analysis on research relating to teacher professional development programs (PDPs) target four interrelated elements that make up effective PDPs—policy, PDPs, teachers and students. The researchers defined the four elements this way:

> Policy includes the federal, regional, state, local, and school policies and standards that help determine the quantity and quality of the PDPs. PDPs include, among other areas, those who offer the programs, the process within the program, the content within the program. Teachers are the participants in the program, with most research examining teacher learning, teacher change and teacher practice. Students are the ultimate beneficiaries for any PDP for teachers, and student-learning outcomes are an important measure of success (p. 892).

But what happens if there are policies in place that are based on new standards that do not have long-standing empirical studies to support their design? What if the content area under study is completely new in an elementary setting, without a cohesive record of how to enact curriculum and instruction so that teachers can teach and students can learn? What kind of professional development can be effective given these parameters? These are not rhetorical questions, for they frame the central issues surrounding the introduction of integrated STEM, engineering and engineering practices into elementary classrooms as core curriculum required by the new Arkansas K-12 Science Standards, which incorporates the Next Generation Science Standards starting in August of 2016 (Arkansas Department of Education, 2005).

According to the 2012 National Survey on Science and Mathematics (Banilower et al., 2012) , while teachers in elementary classrooms have a strong pedagogical knowledge of how to teach in general, they significantly lack the science content knowledge and skills needed in order to teach it effectively. Coupled with low self-efficacy and interest, and lack of exposure towards science in general, elementary teachers must also juggle the needs of an increasingly diverse student population within a high-stakes accountability climate which leaves them very little instructional time to devote to the teaching of science within the classroom (Buczynski & Hansen, 2010; Cunningham, 2009; Guzey, Tank, Wang, Roehrig & Moore, 2014).

The Next Generation Science Standards (NGSS) are performance standards based on the conceptual guiding principles outlined in the Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (National Research Council, 2012). The NGSS provides a unique coupling of science standards with engineering practices as well as supplying integrative connections to the Common Core State Standards for Mathematics and English Language Arts. From a content and pedagogical perspective, the inclusion of engineering as a new elementary content domain has the potential to be problematic as it is neither taught nor learned as a matter of course in American schools, but also because elementary teacher preparation programs do not usually include technology or engineering courses (Lee & Strobel, 2014). Fundamentally, elementary teachers in the field will now have become familiar with engineering as a content area and how it integrates with science and the other domains, while learning how to make all the pedagogical decisions to introduce it effectively within their classroom (Lachapelle & Cunningham, 2014). Professional development will be the avenue by which the majority of the teachers gain this knowledge. However, according to the 2012 Horizon report, 59% of teacher K-5 received professional development in science and of these, 86% spent 15 hours or less in training. If this trend continues, teachers will find it difficult to learn the needed content and pedagogy to successfully bring engineering into the classroom (Banilower et al., 2012).

Purpose of the Study

The purpose of this study is to describe the perceptions and integrative approaches that teachers unfamiliar with engineering and engineering practices take when designing a new curriculum unit of integrated STEM professional development and the subsequent teaching of the unit. The focus is to discern possible areas for future STEM professional development support required for teachers to transition into using the NGSS standards.

Conceptual Framework

The conceptual framework used to guide this study is rudimentary as there is no long-standing body of research with well-developed theories to inform the tack elementary teacher take towards integrating engineering when developing curriculum during the course of professional development of this nature (Rocco & Plakhotnik, 2009). However, there is a large body of research on science teacher pedagogical content knowledge and best practices, characteristics and qualities of effective educational professional development, teacher attitudes, beliefs and how that manifests within the organizational culture, curriculum construction, and types of integration to provide a theoretical context within emergent socio-constructivist perspective. Figure 1 provides the conceptual framework mapping how teachers' different STEM perceptions were analyzed using established theorists in the aforementioned areas of research.

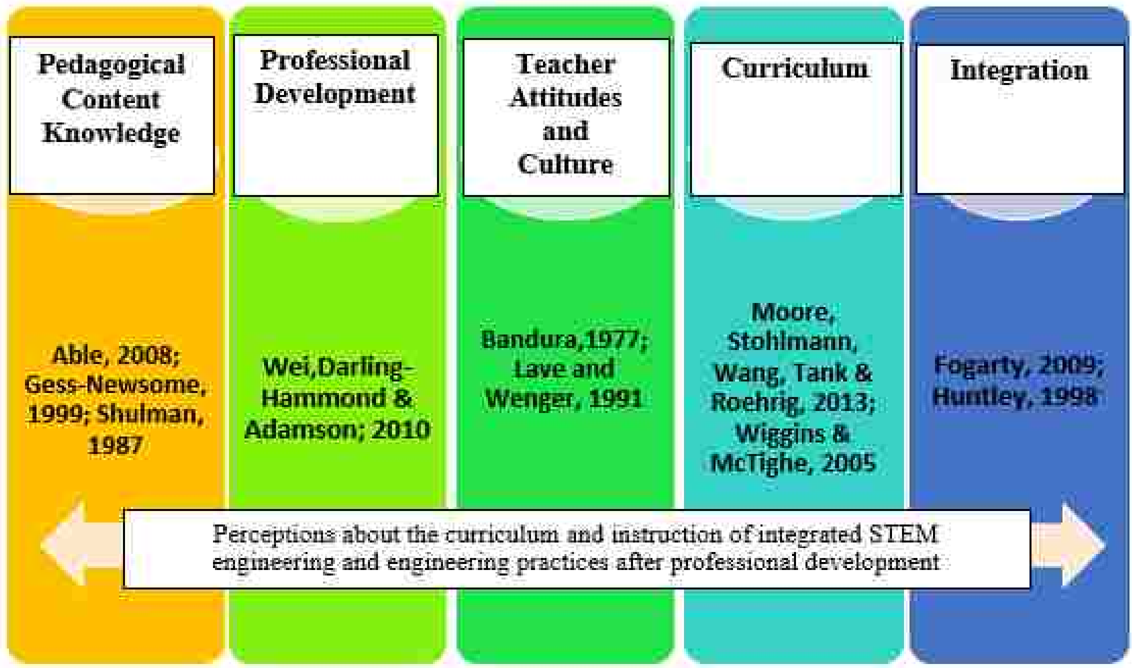


Figure 1. Key Areas of Research and Theorists Used to Support the Conceptual Framework of the Study.

Significance of the Study

The gap in the K-12 engineering and engineering practices research base is noticeable. There are differing opinions on how the various engineering concepts interconnect and integrate with mathematics and science, as well as a lack of understanding of the differences in integrative approaches (Katehi, Pearson & Feder, 2009b). As elementary engineering in K-12 is new, there are few curricula and programs available to ascertain quality of fit for elementary students and classrooms (Miaoulis, 2014). Additionally, there are only a few qualitative studies that address in-service teacher training in elementary engineering and little that focus on how professional development can support teachers' understanding of the NGSS (Moore, Stohlmann, Wang, Tank

& Roehrig, 2014). This study proposes to inform and add to the few existing bodies of knowledge by describing the mental constructs and attitudes teachers new to integrated STEM use. It is believed that that the results of the study will help to inform other elementary schools, teachers, and professional development trainers who are in the process of adopting the NGSS.

Limitations, Delimitations, and Assumptions.

This study has several limitations, the first being the choice to use a case study methodology because of the potential for researcher bias and subjectivity (Yin, 2009; 2012) Second, as a participant observer during part of the professional development training, researcher interactions with the teachers could have influenced some of their behaviors. Third, the teachers were recruited from an already small, self-selected cluster sample (McMillan & Schumacher, 2010). Fourth, the timing of the focus group interviews at the end of the school year was problematic. Fifth, group dynamics within the focus group interviews could repress sharing of views (Harrell & Bradley, 2009a). Sixth, the archival data were inconsistent in how data were collected in some of the cases (Hammersley, 1997; Mauthner, Parry & Backett-Milburn, 1998). Seventh, the qualitative coding was not independently coded by another rater during the course of an inquiry audit (McMillan & Schumacher, 2010).

A delimitation of the study was not to include students, student perceptions or student learning outcomes. While discussion about students did occur within the context of the teachers' conversations concerning their perceptions of teaching the unit, obtaining permission to use students was deemed too cumbersome and outside the core intent of the research.

Two assumptions informed this study. The first was that teachers' implementation of the common grade level curriculum unit would be different in order to meet the situated needs of their students as well as reflecting the teachers' own levels of pedagogical content knowledge related to the curriculum. The second assumption was that there were unknown forces at work which influenced teachers outside the scope of the professional development and that these would influence the teachers' perceptions of the research topics. The use of the semi-structured interviews was anticipated to help uncover and frame what these might be.

Research Questions

This research used a mixed methods exploratory, embedded QUAL[quan] case study design (Nastasi, Hitchcock & Brown, 2010). In this kind of methodology, the qualitative and quantitative data were collected in parallel, with the quantitative data being a smaller component gathered in order to provide insights into teacher perceived self-efficacy. Each was analyzed separately and then merged during the triangulation phase (Creswell & Plano Clark, 2011). There was one central mixed method question with seven sub-questions.

Overarching Mixed Methods Research Question: Does professional development influence elementary teachers' perceptions of the curriculum and instruction of integrated STEM engineering and engineering practices in a 3-5 grade level setting?

- Subquestion 1 (QUAL): Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within their classrooms?
- Subquestion 2 (QUAL): How do engineering and engineering practices manifest within a teacher constructed elementary STEM curriculum unit?
- Subquestion 3 (QUAL): When teachers are constructing STEM curriculum units during STEM professional development, what is the role of engineering in comparison to the STEM subject domains and how is engineering integrated within the unit design?

- Subquestion 4 (QUAL): Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate STEM domains?
- Subquestion 5 (QUAL): Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about how to integrate engineering and engineering practices?
- Subquestion 6 (QUAL): What are the perceived conduits and barriers to effective integration of engineering and engineering practices within an elementary classroom?
- Subquestion 7 (QUAN): Is there a change in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum during the course of STEM professional development?

In order to understand the theoretical underpinnings of each of the research questions, Figure 2 denotes the connection between the seven research questions and the five conceptual framework areas of the study as outlined in the review of the literature. It is important to note that multiple theoretical areas can provide the foundation for the same research question.

Proposed Method.

In the summer and fall of 2014, 20 third through fifth grade teachers in the same district, but from three different elementary schools, chosen because of their close proximity to a regional airport, embarked on an 80 hour grant funded course of professional development on aviation, integrated STEM, and STEM curriculum unit construction with the teachers teaching the unit during the fall of 2014. The group of teachers met for a two-week eight-day workshop in June, with two follow-up trainings in the fall resulting in a total of 80 face-to-face professional

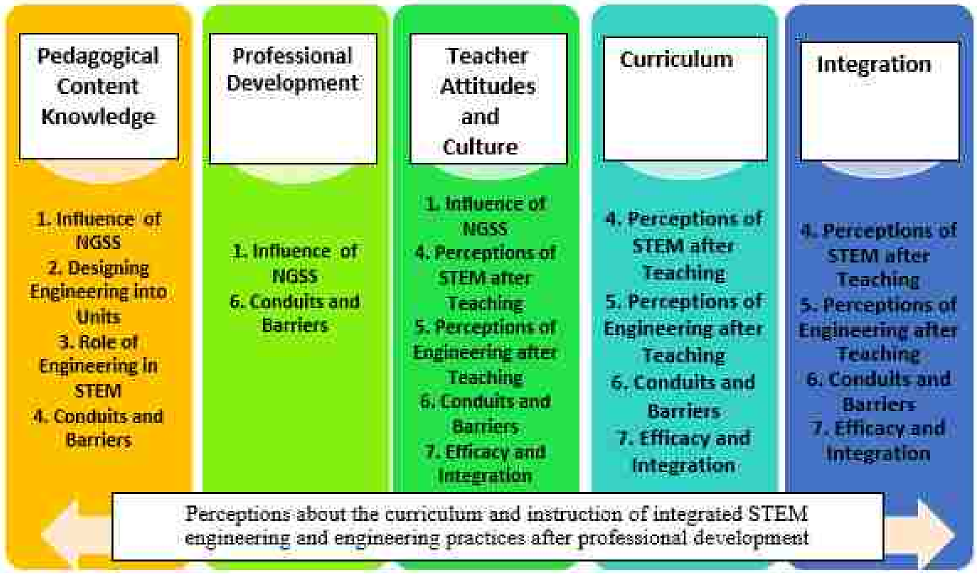


Figure 2. Relationship of Research Questions to Conceptual Framework Elements.

development hours as indicated by research as the minimum required to change teacher praxis (Supovitz & Turner, 2000).

Archival data used for this study were collected during the summer and fall of 2014. The qualitative data consisted of the following: daily agendas (Appendix A), handouts (both physical and electronic), PowerPoints, photographs, two culminating group presentations and the materials connected to them, items posted to the two Padlet resource sites (Appendix B) , the final grade level curriculum units (Appendix C-E), and the Project Flight final report. Qualitative data were collected from comments on the nine exit cards (Appendix F), Project Flight Pre/Post tests (Appendix G), and four pre and post STEM-TEBIs (Appendix H). Top down *a priori* quantitative coding data was done on the archived data.

New data were collected during the course of semi-structured focus group interviews with 14 out of the original 20 teachers who agreed to be part of the follow up study during the first week of June 2015. Qualitative data were derived from the recorded interviews, transcripts, Think-Write-Shares, and from teacher analysis of two curriculum documents—their grade level

Understanding by Design curriculum unit and a teacher selected STEM lesson plan. Inductive bottom up coding of the new quantitate data was done. New qualitative data were obtained from a post-post STEM-TEBI and two questions from the Project Flight Pre/Post test.

Then, descriptive statistics for the summer training exit cards, as well as four sequential data collection points for Questions 9 and 10 on the Pre/Post tests, were run using the Statistical Packages for the Social Sciences (SPSS). Using the same software, STEM TEBI scores for the first ten questions of the measure were contrasted using repeated measured ANOVA tests. Table 1 illuminates more fully how each source of data links to the subquestions of the main research question:

> Does professional development influence elementary teachers' perceptions of the curriculum and instruction of integrated STEM engineering and engineering practices in a 3-5 grade level setting?

Table 1
Archival and New Data Sources Aligned to Research Subquestions

Research Subquestions	**Archived Data**	**New Data**
1 QUAL: Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within their classrooms?	•Exit cards •Pre/post test •Project final report	Focus group interview •Think-write-share
2 QUAL: How do engineering and engineering practices manifest within a teacher constructed elementary STEM curriculum unit?	Daily agendas •Handouts •PowerPoints •Padlet •Photographs •June grade level unit presentation	November presentation and lesson •Final curriculum units •Project final report •Focus group interview •Think-write-share •Curriculum unit •Teacher stem lesson

Table 1 (Cont.)
Archival and New Data Sources Aligned to Research Subquestions

Research Subquestions	Archived Data	New Data
3 QUAL: When teachers are constructing STEM curriculum units during STEM professional development, what is role of engineering in comparison to the STEM subject domains and how is engineering integrated within the unit design?	•Daily agendas •Handouts •PowerPoints •Padlet •June grade level unit presentation •November presentation and teacher lesson	•Final curriculum units •Project final report •Focus group interview •Think-write-share •Curriculum unit •Teacher stem lesson.
4 QUAL: Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about how to integrate STEM domains?	•November presentation and teacher lesson •Final curriculum units	•Focus group interview •Curriculum unit •Teacher STEM lesson.
5 (QUAL): Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about how to integrate engineering and engineering practices?	•November presentation and teacher lesson •Final curriculum units	•Focus group interview •Think-Write-Share •Curriculum unit •Teacher STEM lesson
6 QUAL: What are the perceived conduits and barriers to effective integration of engineering and engineering practices within an elementary classroom?	•Project final report	•Focus group interview •Think-write-share
7 QUAN: Is there a change in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum during the course of STEM professional development?	Pre/post STEM-TEBI •Project final report •Pre/post test	Post-post STEM-TEBI •Pre/post test.

The three data sets were triangulated using non-cross over data analysis of the archival data, the current data, and the 2015 quantitative testing to describe the teachers' perceptions and integrative approaches of teachers at the same grade level and between grade levels at the same school. The study's conceptual framework was used to guide the discussion of the trends and broad themes derived during the triangulation process and the recommendations that follow.

Definition of Terms

While there are many terms used in the research, those most connected to the research questions are defined below.

Arkansas Science Standards are the current state science content standards. Revised in 2005, the standards encompass life science, earth and space science, physical science and the nature of science (Arkansas Department of Education, 2014)

Creativity is any act, idea or product developed by a person or a group that transforms something that already exists or develops it into something new (Csikszentmihalyi, 1996). In the case of this study, creativity in engineering is categorized into four levels: replicative design, combinatorial, exploratory and transformational creativity (Boden, 2001).

Communities of Practice are "formed by people who engage in the process of collective learning in a shared domain of human endeavor" (Wenger-Trayner, 2015, para 3). In the case of this study, it is the members who undergo professional development.

Engineering is the "process of designing the human made world" and also a process for solving problems under constraints (Katehi et al., 2009b, p. 27).

Engineering Design is the "systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraint" (Brophy, Klein, Portsmore & Rogers, 2008, p. 372).

Engineering Design Loop is a four to eight step process to test engineering solutions and collect data that has a rough correlation to different experimental designs used by scientists but with a different focus (Daugherty, 2012).

Engineering Habits of Mind are the "values, attitudes, and thinking skills associated with engineering" which include: creativity, collaboration, communication, optimism; systems thinking, and attention to ethical considerations (Katehi et al., 2009b, p. 152).

Inquiry as defined for use within the classroom, is defined as "the activities of students in which they develop knowledge of scientific ideas, as well as an understanding of how scientists study the natural world" (National Academy Press, 2009, p. 23).

Integration is a" holistic approach that links the disciplines so that learning becomes connected, focused, meaningful, and relevant to the learners" (Moore et al., 2014, p. 38).

Nature of Science is a set of dispositions used by science and scientists in the field that provide a conceptual framework for the study of science within the classroom (Akerson & Hanuscin, 2007).

Next Generation Science Standards are new multi-state science standards based on policies developed by legislative educational reform policy, to create standards that are " rich in content and practice, arranged in a coherent manner across disciplines and grades to provide all students with an internationally benchmarked science education" (NGSS Lead States, 2013, p. xiii). Preparing Arkansas teachers to use these new standards via professional development is the focal point of this study.

Pedagogical Content Knowledge is the overarching heuristic encompassing seven forms of teacher knowledge. It is "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8).

Professional development is the "comprehensive, sustained, and intensive approach to improving teachers' and principals' effectiveness in raising student achievement" (Wei, Darling-Hammond & Adamson, 2010, p.4).

Science is the “study of the natural world where the process of scientific inquiry is used to generate new and useful knowledge” (Katehi et al., 2009b, p. 27). Science and engineering within the Next Generation Science Standards are presented as mutually reinforcing disciplines.

Scientific methods are processes by which scientists develop and test theories using experimental designs. The process is a rough correlate to the engineering design loop but with a different intent (Daugherty, 2012).

Science Process Skills are a set of basic and integrated developmentally appropriate science skills used when conducting science inquiry within the elementary classroom. (Wheatley, 1991).

Self-Efficacy is the “personal belief about one’s ability to be successful when undertaking a new or ambiguous task” (Gredler, 2009, p. 350).

Self-Regulation is a learner's “proactive efforts to mobilize emotional, cognitive and environmental resources during learning and self-observation, judgment, and reaction to one’s process” (Gredler, 2009, p. 350).

STEM (Science, Technology, Engineering, and Mathematics), according to Lee and Strobel (2014) , is the acronym for a new content area being introduced into education K-12 wherein all four of the disciplines are integrated. Within the context of this study, science and engineering are the main areas discussed.

Technology involves the “artificial world” of human-made artifacts and how to add to and maintain that world for societies’ benefit (Cross, 2001).

Understanding by Design is a curriculum method developed by (Wiggins & McTighe, 2005) using backwards design to construct units, performance assessments and instruction by first starting with the end student learning outcomes in mind. In this study, it was the method used by the teachers to create their curriculum unit.

Conclusion

In sum, the purpose of the study was to understand the perceptions and integrative approaches that teachers unfamiliar with engineering and engineering practices take when designing a new curriculum unit through the course of integrated STEM professional development with the research intent being to discern possible areas for future STEM professional development. Five elements form the conceptual framework for the study: science teacher pedagogical content knowledge and best practices, teacher attitudes and beliefs, characteristics and qualities of effective educational professional development, and curriculum construction and types of integration. This mixed methods case study design centers upon one main question and seven sub-questions in order to begin to build a body of research on engineering and engineering practices K-12.

Chapter 2. Literature Review

Introduction

Sensemaking is the approach people use to deal with the unknown within organizational settings. It involves trying to find resolution between old personal goals and the new organizational goals and gaining an understanding of new roles and responsibilities all of which can be hampered by a person's lack of knowledge concerning the degree of change to the system itself and to individual people within the system (Allen & Penuel, 2014). Elementary teachers have undergone a systemic change with the implementation of the Common Core State Standards (CCSS) regarding mathematics and English/Language Arts in the classroom (Porter, McMaken, Hwang & Yang, 2011). The Next Generation State Standards (NGSS), will serve as the foundation for the new Arkansas K-12 state science standards in the fall of 2016 (Arkansas Department of Education, 2014) and will require a similar sensemaking recalibration by elementary teachers in their teaching of science in terms understanding how the NGSS standards function within the *recommended* curriculum—that espoused by experts in the field, professional organizations, reform commissions, and policy making groups with how the standards function with within the *ideal* curriculum— determined by scholars and experts in the field and deemed to be quality instructional practice by teachers in their classrooms (Glatthorn, Boschee & Whitehead, 2009).

The development of both the CCSS and NGSS standards were in response to national educational reforms over the last decade, predicated upon the belief that the United States is losing its ability to compete within the global economy and the lagging academic performance of American students compared to students from other countries (NGSS Lead States, 2013). Core recommendations of reform policy makers was to develop a technologically literate, vibrant democratic citizenry via the construction of K-12 educational pipeline to assure an adequate number of future science, technology, engineering, and mathematics (STEM) professionals to promote a future national culture of innovation (Common Core State Standards Initiative, 2012; Katehi et al., 2009b ; Miaoulis, 2014).

In order to frame the nature of elementary teacher STEM professional development to help support elementary teachers in their sensemaking of the NGSS in Arkansas, the following topics are discussed: (1) the current educational environment for STEM; (2) elementary teachers' lack of science and engineering pedagogical content knowledge; (3) integrated STEM within the context of professional development; (4) the differences between NGSS and the current Arkansas state standards; (5) the role of teacher beliefs regarding systemic change, and (6) proposed professional development support areas for teachers in order to transition to the NGSS.

Framing the Current Elementary STEM Environment

Elementary science teacher demographics. The 2012 National Survey of Science and Mathematics Education (NSCMS), funded by the National Science Foundation (NSF), provides current data on the nation's science teachers (Trygstad, 2013). The study involved 7,752 science and mathematics teachers across the United States, and was "designed to provide up-to-date information and to identify trends in the areas of teacher background and experience, curriculum and instruction, and the availability and use of instructional resources" (Banilower et al., 2012, p. 1). Elementary science teachers, nationally, are overwhelmingly white females, with half being o 40 years old with 11 years or more of classroom experience. A third of all elementary teachers have five or fewer years teaching science (Trygstad, 2013). Sixty-two per cent of the all elementary teachers hold a bachelor's degree, 13% hold a bachelor's degree with some post-baccalaureate hours, and 25% have a master's degree or higher qualification.

In terms of science content, only 5% of elementary teachers hold college or graduate degrees in science, engineering, or science education. Given that elementary science teachers are expected to teach across all the science disciplines, the National Science Teachers Association (NSTA) recommends that teachers take college courses in life, earth, and physical science (Trygstad, 2013).NSSME data shows that, as of 2012, 36% of teachers had taken courses in all three areas and 38% had taken two. One per cent of K-5 teachers had taken a course in engineering (National Center for Science and Engineering Statistics, 2014).

Furthermore, according to the NCSES, 59% of the teachers had participated in science professional development within in the previous three years. Sixty-five percent of the teachers had professional development that lasted less than six hours while only 4% had professional development that lasted more than 35 hours. Thirty percent of the teachers stated they were well prepared to teach science, which is less than the 81% of teachers who felt confident to teach language arts or the 77% to teach mathematics. Of the teachers who were confident teaching science, slightly more than 25% felt prepared to teach life and earth sciences, 17% the physical sciences, with 4% to teach engineering.

Science in the classroom. These demographic findings are problematic for elementary STEM education given the current climate of state mandated testing where what is taught and privileged in classrooms is directly tied to national and state content standards and benchmark achievement tests (Brophy et al., 2008). With the demands of high-stakes accountability, only half of the current elementary teachers participated in science professional development within the preceding three-year period, compared to other subject areas (Banilower et al., 2012). Only 25 minutes per average school day are spent on science and, while generally commensurate with the time spent on social studies, trails significantly in comparison to the 111 minutes spent on English Language Arts or the 64 minutes spent on mathematics (Flup, 2000).

Science, technology, engineering and mathematics are the core disciplines under the STEM education umbrella which have, over the last decade, made inroads in replacing science as a content area in elementary classrooms. Sneider and Purzer (2014b) , in *The Rising Profile of STEM Literacy through National Standards and Assessments*, maintain that science and mathematics teachers have always used some form of technology and engineering elements while teaching to provide a real world context based on the premise that it will lead to higher student understanding of the two core subjects. The authors argue, however, that the definition of STEM *literacy* has expanded beyond more than the knowledge required for any one particular course of study or knowledge used in preparation for a job and now embraces the scope of what all people should do and know in order to function in a modern world.

Defining STEM.

The Committee on K-12 Engineering Education (2009) defined the four STEM domains and their interactions with each other, in the following ways:

> *Science* is the study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment and application of facts, principles, concepts, or conventions associated with these disciplines. Science is both a body of knowledge that has been accumulated over time and a process—scientific inquiry that generates new knowledge. Knowledge from science informs the engineering design process.
>
> *Technology* comprises the entire system of people and organizational knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves. Throughout history, humans have created technology to satisfy their wants and needs. Much of modern technology is a product of science and engineering, and technological tools are used in both fields.
>
> *Engineering* is both a body of knowledge—about the design and construction of human-made products—and a process for solving problems. The process is design under constraint. One constraint in engineering design is the laws of nature, or science. Other constraints include such things as time, money, available materials, ergonomics,

> environmental regulations, manufacturability, and reparability. Engineering utilizes concepts of science and mathematics as well as technological tools.
>
> *Mathematics* is the study of patterns and relationships between quantities, numbers, and shapes. Specific branches of mathematics include arithmetic, geometry, algebra, trigonometry, and calculus. Mathematics is used in science and in engineering (p. xxxiii).

According to Sneider and Purzer (2014b) , the expectation for teachers under the current educational reform, is that the teachers need to be well versed to teach all *four* STEM domains *equally* [italics are mine] well. To do so requires a body of content knowledge in all four areas, but also an understanding of how the various fields relate to each other, as well as best practices for teaching it in the classroom. This means aligning teachers more towards the *recommended* curriculum of the policy makers than the *ideal* curriculum of content area experts and pedagogical best practice. Doing so will be challenging. Elementary education certification typically required the completion of two college-level science and mathematics courses (Nadelson et al., 2013; National Research Council, 2012). Elementary state-level certifications do not require classes in engineering to receive initial certification (Miaoulis, 2014). As noted in the NSSME 2012 data, half of in-service teachers have not had science professional development in the preceding three years and a third of the teachers have been teaching science for less than five years. Finding ways to increase participation in professional development is of import, particularly in light of the requirements and expectations of the CCSS and the NGSS.

Understanding the Genesis of the NGSS

STEM, as an elementary content area, is a new development. The Elementary and Secondary Education Act (2002, 2015), also referred to as No Child Left Behind (NCLB), requires that each state have articulated standards—defined as the mandated knowledge, skills, and processes students are required to achieve by specific points in their educational careers (Glatthorn et al., 2009) and assessments for mathematics, science, social studies, and English.

The National Council of Teachers of Mathematics (National Center for Science and Engineering Statistics, 2014) standards were published in 1989, and served as the progenitor for numerous state mathematics standards across the country (Brophy et al., 2008.; Carr, Bennett & Strobel, 2012; Sneider & Purzer, 2014b). In the same year, *Science for All Americans* was published by the American Association for the Advancement of Science. Within it, engineering as a K-12 content area was introduced in two chapters: "Engineering Combines Scientific Inquiry and Practical Values" and "The Essence of Engineering is Design under Constraint" (1989, pp. 40-41).

Science, engineering, and technology were all notably linked when the National Research Council (NRC) published the *National Science Education Standards* (National Research Council, 1996) which are referenced overwhelmingly by standards-based science instructional materials and numerous state science standards (Sneider & Purzer, 2014b). The NSES stipulated the core aspects of the content domains, set expectations for the evaluation of student achievement, and delineated appropriate science professional development for teachers. In 2000, the International Technology Education Association published the *Standards for Technological Literacy: Content for the Study of Technology* which gave significant attention to engineering design after being reviewed by both the NRC and the National Academy of Engineering (NAE) (Bybee, 2010).

In 2001, Massachusetts was the first state to include the full complement of STEM domains within its state science standards. According to Carr, Bennett, and Strobel (2012) , thirty four states have followed suit. *Rising above the Gathering Storm* (Augustine, 2005) , initiated by legislative committees in both houses, was charged with making policy recommendations for science and technology in order for the United States to be able to "compete, prosper and be secure" in its place within the global community. Four of these recommendations can be directly tied to changes in K-12 science and mathematics educational reform policy as discussed in the opening paragraphs of this chapter. In 2009, the NAE position published *Standards for K-12 Engineering Education*? a position paper which discussed the viability of national engineering standards. Furthermore, the topic was also discussed in *Engineering in K-12 Education: Understanding the Status and Improving the Prospects,* which described the current state of engineering education in the United States (Carr et al., 2012). However, as of 2015, there are still no engineering domain specific national standards that have been proposed which makes engineering the one STEM content area which lacks a set of professionally codified, domain specific standards (Bybee, 2010).

The CCSS for English Language Arts and Mathematics is currently under intense scrutiny and political pushback. The CCSS were initiated in 2008 by the National Governors Association in reaction to the low mathematics and science scores of American students on international tests, unease with American economic competitiveness in a global market, and were based on the assertion that many standards do not align curriculum, instruction, and assessment in a cohesive and tangible way. The CCSS are currently active in 43 of the original 46 states that adopted them (National Governors Association & Council of Chief State School Officers, 2015; Sneider & Purzer, 2014b). The focus and expectations of the Common Core State Standards for Mathematics (CCSS/M) are markedly different from numerous older state standards. Less stress is placed on memorization and knowledge of procedures. The demonstration of understanding by solving non-routine problems is doubly evident in the CCSS/M. There are increased cognitive demands for analytical and critical thinking, particularly in using evidence to support claims and requiring proof of analysis (Kendell, 2011; Porter et al., 2011). Of particular import is the structure of the mathematics. Groups of related standards, which reflect core aspects of domain knowledge, are gathered into *clusters.* These clusters link across grades and are used to promote large conceptual understandings, develop key procedural skills, and reinforce application of knowledge in many different contexts (Alberti, 2012; Kendell, 2011). The different CCSS/M expectations of increased evidence of understanding, deeper analytic thinking, and spiraling of concepts throughout the grades are just a few of the elements that required teacher shift in praxis.

The NRC reworked its science standards in *A Framework for K-12 Science: Practices, Crosscutting Concepts and Core Ideas* in 2012. Science, engineering and technology were clearly delineated as specific content domains, equal weight was granted to both science inquiry and engineering design, and science and engineering practices were integrated into the various science fields and concurrently linked to the appropriate grade level CCSS for both mathematics (CCSS/M) and English/language arts (National Research Council, 2012; Sneider & Purzer, 2014b).

The NGSS, like the CCSS, was developed by Achieve, Inc. They were released in April 2013, and are based on the Science Frameworks. As in the case of the CCSS, economic and political pressures were the stated motivations for the development of the NGSS. Fewer students, it was claimed, were entering engineering at a post-secondary level. Furthermore, concerns were voiced that the country was not preparing enough students, teachers, and future practitioners in the areas of science, technology, engineering, and mathematics to meet the needs for continued American success in the future (National Governors Association & Council of Chief State School Officers, 2015; NGSS Lead States, 2013).

The states have approached the adoption of the NGSS in different ways. Some, like Massachusetts, incorporated aspects of the NGSS into their own state developed standards.

Others, like Nevada, required large school district implementation teams and statewide science professionals to collaborate with the Next Generation Science Education network as part of the input process during the formulation of new state standards (Best & Dunlap, 2014). Wyoming, after an 18 month moratorium on spending state funds on reviewing the NGSS due to concerns on how climate change was presented in the standards, lifted the ban in March of 2015 and are now in the process of review (Best & Dunlap, 2014; Schrank, 2015).

In June of 2015, Arkansas adopted the NGSS science standards for grades K-8 (with grades 9-12 currently under development) bringing the total of states to adopt the NGSS up to fourteen (Heitin, 2015). The new Arkansas K-8 Science Framework integrate the STEM domains by endorsing science, engineering, and technology as the disciplinary core ideas to be used in conjunction with the ELA and mathematics of the CCSS (Arkansas Department of Education, 2015). Arkansas, one of the original draftees of the NGSS standards along with 26 other states (Best & Dunlap, 2014) , retained the NGSS performance standard expectations (PEs) and also included some Arkansas state specific examples and non-tested optional content assessments using clarification statements and an AR designation (Arkansas Department of Education, 2015). Like the CCSS before it, the Arkansas K-8 Science Framework will require a different approach by teachers to meet the new curricular requirements of the science standards.

Teacher Science and Engineering Pedagogical Content Knowledge

In this section, after introducing Shulman's pedagogical content knowledge theory, a discussion concerning the manifestation of inquiry within science and in engineering is outlined by comparing of the following: each domain's theoretical underpinnings, science methods and engineering design, and the Nature of Science (NOS) practices and engineering habits of mind. Science starts the dialog, followed by a section which examines the dearth of empirical research on teacher knowledge bases of engineering and engineering practices K-12, with engineering finishing the discussion.

Pedagogical Content Knowledge. Prior to 1986, process-product research, which delineated what teaching behaviors could be scientifically studied for classroom effectiveness was at the forefront of educational research. Research on teacher education itself was emerging as a specific area of concentration apart from the general research on teaching (Cochran-Smith & Fries, 2005).

In 1986, Shulman proposed a new line of research in teacher education called *pedagogical content knowledge* (PCK), which involved "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8). Unlike the prior disparate research studies, Shulman's innovative research approach used a synthesis of six kinds of teacher knowledge: content knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners, knowledge of educational context, and knowledge of aims and philosophical purposes of education. His aim was to develop a dynamic heuristic for teacher cognition in which PCK transformed the other six knowledge bases into a synergistic whole when applied to a teacher's praxis and the content (Abell, 2008; Gess-Newsome, 1999). For a robust PCK in a content area, teachers must have the knowledge of the specific content and of the substantive frameworks that guide inquiry in order to make sense of information within the subject area. Furthermore, they must have a good grounding in the syntactical structures used by experts in the field to validate that the knowledge they generate will fit within the specific perimeters of the content domain itself (Barnett & Hodson, 2001; Grossman, Wilson & Shulman, 1989; van Driel, Berry & Meirink, 2014).

Science Pedagogical Content Knowledge (SPCK). The 2012 NSSME demographic data support the assertion that most elementary teachers lack the specific science and engineering pedagogical content knowledge to teach the subject effectively. Science teaching requires skills in discerning student conceptualization of science content and processes. It also requires knowledge of science inquiry, process skills, and curriculum as well as the use of strategic assessments and domain specific orientations, such as the nature and philosophy of science for the teaching of science (Magnusson, Krajcik & Borko, 1999 ; Park & Oliver, 2008; Schneider & Plasman, 2011). There have been sufficient empirical studies of the attributes of SPCK to make research based decisions on effective science K-5 teaching and learning. However, the goal of science education is not the creation of new knowledge, which is the domain of scientists in the field, but "to help students understand an existing, consensually agreed upon and well-established old knowledge" (Osborn, 2015, p. 580).

Research by Appleton (2008) notes that elementary science teachers SPCK is a very topical, specific PCK which is highly activity based. Rarely do elementary teachers move on to specific science domain PCK, biology for example, because as generalists, the teachers seldom have a science area of specialization. Consequently, the elementary teachers' understanding of a large spectrum of ways to teach science over domains rarely occurs.

To teach science effectively, elementary teachers also need a working understanding of how science literacy manifests within students. Science literacy is defined as:

> the knowledge of the key facts, concepts, principles, laws and theories of the science disciplines, as well as the ability to connect ideas across disciplines and apply them in new situations. It also includes the reasoning ability to support claims from evidence, to reflect on the nature of science and one's own thinking, and to participate productively with peers in scientific discussions (National Assessment Governing Board, 2010, p. 8).

In order to encourage science literacy in their students, elementary teachers have to make a protracted effort to move beyond the topical SPCK and obtain more domain and discipline related SPCK.

Constructivism. Quality science instruction is based on constructivist theory and practices, predicated by the Piagetian assertion that all learners actively self-construct their own knowledge. "Ideas and thoughts cannot be communicated in the sense that meaning is packaged into words and 'sent' to another who unpacks the meaning…as much as we would like to we cannot put ideas into students' heads" (Wheatley, 1991, p. 10). This construction of knowledge, however, takes place within a social context which leads to the Vygotskian assertion that knowledge is co-constructed as learners participate "in joint enterprise in which meaning is derived through interaction with other people, mediated through language [and discourse]" (Howe, 1996, p. 45).

Constructivism requires teachers to take a diagnostic and facilitative stance, which is often at odds with most elementary teachers' long apprenticeship of observation, both as students and as professionals (Abell, Rogers, Hanuscin, Lee & Gagnon, 2009; Hanuscin, Lee & Akerson, 2010). This practical, or craft, knowledge is the highly situated, amalgamated wisdom of the multiple lessons learned throughout a teacher's career and is embedded with unarticulated beliefs and values which shape the professional and instructional choices made by the teacher (van Driel et al., 2014). As such, elementary teachers' craft knowledge can lead them to use a more transmissive style when teaching science, where teacher pre-conceptualized "correct" information is passed directly from the teacher—or through prescriptive teacher selected materials and activities—to the students didactically. The need to retain teacher control over the students and flow of information in the classroom is also embedded within teacher craft knowledge (Schneider & Plasman, 2011).

Inquiry and Methodology. Current research and standards for best practice stress the importance and use of science inquiry in the elementary classroom. Inquiry is a process that can be categorized in two different ways. The first, pioneered by Schwab (1960), the use of inquiry within the classroom was to help students understand the thought processes and actions of scientists in the field. This kind of inquiry, defined by the National Education Science Standards, as “the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work” has nuanced differences from student inquiry in the classroom, which is “the activities of students in which they develop knowledge of scientific ideas, as well as an understanding of how scientists study the natural world” (National Research Council, 1996, p. 23).

The National Research Council has laid out a broad framework for inquiry by students in the classroom, which requires the following elements:

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations for evidence to address scientifically oriented questions.
4. Learners evaluate their explanation in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their posed explanations (National Academy of Science, 2000, p. 25).

From a teacher's perspective, according to Minner, Levely, and Century (2010) , inquiry with students is supported by a designated science content topic, student active engagement, and student responsibility for learning, thinking about, or motivation toward an aspect of instruction—whether it be designing a question for investigation, developing the design or display of the data, or communicating the results of the activity. The gradual release of responsibility and control from teacher to student ownership is important for the education process and level of inquiry within the classroom and is dependent, in part, upon the students' abilities to perform the process skills and the teacher's ability to structure activities that foster student understanding of how to do so.

Process Skills: The basic and integrated process skills, as defined by the National Association for Research in Science Teaching, according to Padilla (1990), form a developmentally appropriate sequence of science process skills within the science classroom. For students within the preoperational and concrete operational stages, the K-4 process skills of observation, inference, measurement, communication, classifying, and predicting is within the younger students' developmental wheelhouse. The integrated science process skills, which are phased in near the end of third grade, include controlling variables, defining how a variable is measured operationally, formulating hypotheses, interpreting data and forming conclusions based on the data, learning how to conduct an experiment, and constructing a mental or physical model of a process or event are more appropriate for intermediate students.

Settlage and Southerland (2007), state that once students have become more adept in understanding how to do the measuring and the procedures, as well as developing skills in interpreting the results, they are then ready to move on to having more control over the designing process. As the teacher relinquishes control, different levels of inquiry are available to the students. The lowest level is not considered inquiry learning but confirmatory in nature and is characterized by the teacher posing the question, ways to gather data, guidance on how to interpret the results, as well as expected results. Structured inquiry opens up the end result to student investigation while guided inquiry students also develop the design procedures. The highest level of inquiry, open inquiry, is where students, with the agreement of the teacher, control all aspects of the investigation (Bell, Smetana & Binns, 2004; Rezba, Auldridge & Rhea, 1999; Shulman, 1987).

Nature of Science. In a dispositional sense, in terms of understanding how real scientists approach science, using the Nature of Science (NOS) concepts addresses the third component of Schwab's definition of student inquiry while providing a strong conceptual framework to integrate disparate science concepts and topics together under one umbrella. While there is not total agreement on the number and wording of all the NOS concepts, there are six that are generally agreed upon as applicable and developmentally appropriate for an elementary setting. Akerson and Hanuscin (2007), found that

> …scientific knowledge is both durable and tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), subjective or theory-laden (influenced by prior-knowledge and theoretical frameworks of the researcher), partly the product of human inference, imagination, and creativity (involving the invention of explanation), socially and culturally embedded (both influences and is influenced by the cultural milieu), and utilizes both observation and inference (p. 3).

Conceptual Change. Goris and Dyrenfurth (2010), framed their discussion of students' alternate or naïve conceptualizations of science phenomena on the original work of Smith et al. Students are assumed to always come into the classroom with some understandings of a phenomena based on their real life experiences which, in most cases, differs from those accepted within the science disciplines. These alternative conceptions can be strongly held, widespread, and extremely resistant to change. They can exist concurrently, although departmentalized, alongside more scientifically aligned understandings and can thwart the forward movement of the learning process within students. The replacement or removal of naïve misconceptions by more expert ones is central to the research on conceptual change. "Instruction [confrontation] begins as an 'external, social interaction in the classroom, but for confrontation to succeed, the competition between misconception and expert concept must be internalized by students… successful instructional confrontation leads to learning by replacement'" (p. 5). For successful replacement of an existing idea, whether partial or whole, a new concept has to be intelligible, or make obvious sense to the learner, and it has to be plausible in that it has the possibility to be true. It also must be perceived to be fruitful, in that the learner thinks that it can be of use to solve the problem at hand. The mission of the teacher is to design a learning situation that sets the learners up to be dissatisfied with and conflicted by their current understandings of a concept (Strike, 1982). These shifts generally do not come quickly but, rather, they emerge gradually over time as the learner goes through the process of assimilating and accommodating new information into his existing framework of beliefs and understandings, and through discourse with others, towards increasing connections and depth appropriate for the students' developmental level and ability to undertake abstract thinking. As teachers, the goal is to ascertain and use the naïve conceptions as starting points to lay the foundation on which to build the students' understanding of scientific phenomena as the learner's "move back and forth between everyday concepts and scientific concepts, fitting them together, discarding some ideas and accepting others" (Howe, 1996, p. 49).

Science curriculum knowledge. Unfortunately, novice science teachers do not recognize the inaccuracy of their own understanding and therefore they fail to recognize it in their students. Consequently, the teachers may actually end up reinforcing their mutually shared misconceptions (Magnusson et al., 1999; Smith & Karr-Kidwell, 2000). The inquiry approach requires that teachers' content knowledge has to be deeper and broader in order to contend with the myriad different questions their students will have. Teachers with a high degree of subject matter knowledge not only have a marked understanding of the facts and constructs of the discipline but also a refined knowledge of the connections between them. These teachers are able understand the hierarchies found within the knowledge bases and are able to know which "questions and hypotheses will lead to better understanding or confusion [in their students]" (Alake-Tuenter, Biemans, Tobi & Mulder, 2013, p.16). According to the conceptual change model of instruction, teachers must purposely build ways to help students change these misconceptions during instruction. Consequently, the less sophisticated a teachers' science content knowledge, the less they are able to plan for conceptual change within their students through strategic questioning. Novice science teachers tend to ask rhetorical or closed, low-level questions that do not foster higher order critical thinking questioning that fosters explication from the students because the teachers, themselves, do not have a depth of content knowledge needed. Because of this lack, there also tends to be little opportunity for collaboration between students or chances for active learning that also build higher order science understandings within the learners.

For all of these reasons, science taught through constructivist inquiry methods "baffles, scares and even annoys a large portion of educators—it requires new behaviors for many teachers who learned science and how to teach it in conventional ways" and "if teachers do not believe philosophically in teaching for understanding rather than dispensing information, this role will be rejected"(Levitt, 2001, p. 2, 3) If the foundation for teaching science is weak, adding another content area to it will be problematic.

Dearth of Empirical K-12 Engineering Research Studies

Empirical research concerning engineering in a K-12 setting is at its beginning stages with scant focus on elementary engineering teachers (Lambert et al., 2007). In her speech before the U.S. House of Representatives subcommittee on Research and Science Education in 2009, Linda Katehi, when presenting the *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* policy report, was blunt in her argument. Even though policy makers, driven by economic and global competitiveness concerns, had reached a consensus that K-12 STEM had to be improved, there were no learning standards for K-12 engineering developed, little guidance for teacher professional development, no state or national level assessments, nor one central organization to collect information on K-12 engineering education (Katehi, Pearson & Feder, 2009a).

In 2010, the Committee on Standards for K-12 Engineering Education argued against developing engineering standards at that time. The argument was based on the dearth of empirical research and the lack of practical, anecdotal experience in the field required to provide the guidance needed to understand the theory behind teaching and learning engineering at a pre-college level, or when topics should be introduced, at what level of complexity, and how key engineering concepts would interact with each other, as well as with the other STEM areas, which were needful to write sound engineering standards (National Academy of Engineering, 2010).

However, when the Next Generation Science Standards (NGSS) were released in 2013 they included K-12 engineering standards and engineering practices within the context of three-pronged design. As outlined in Framework for K-12 Science Education (2012) , the first prong, *Scientific and Engineering Practices*, engineering design and technology applications had the same weight as scientific inquiry within the standards. The second major element was the *Disciplinary Core Ideas* (DCI). The DCI have designated core science concepts which spiraled through grades K-12 in the earth and space sciences, life sciences, and physical sciences. However, the DCI also included a new integrated domain area, that of engineering, technology and application of science which was to be taught alongside the three others. Here, the engineering design thinking and processes are related to the influence of and links between engineering and technology, science and society. The final prong of the NGSS standards were the Crosscutting Concepts, seven broad themes designed to help students organize and integrate knowledge across all the DCI domains. Additionally, each of the NGSS standards within a DCI domain per grade level, came with appropriate cross-links to CCSSELA and CCSS/M standards.

Unfortunately, the research used to develop the engineering within the NGSS was cobbled together from more discrete research from the other STEM disciplines (Diefes-Dux, 2014). Interestingly, the Frameworks make do make reference the recommendations of the Committee for Standards for K-12 Engineering Education in the following quote yet do not directly address the lack of engineering empirical research:

> The 2010 National Academy of Engineering *Standards for K-12 Engineering Education* concluded not appropriate at present to develop standalone K-12 engineering standards. But the report also made it clear that engineering concepts and skills are already embedded in existing standards for science and technology education, at both the state and national levels—and the report recommended that this practice continue (p. 204).

Within the report, the argument for including engineering K-12 was that it effectively serves as connector for, and conduit of, the meaningful learning of science and mathematics by students, encourages an interdisciplinary approach to teaching which incorporates knowledge from multiple domains, and heightens student skills in problem solving, creative thinking, and communication (Moore et al., 2014; National Academy of Engineering, 2010).

As a body, integrated STEM research lacks the needful longitudinal studies that accumulate over time. The data from the limited number of studies on integrated STEM tend not to be generalizable to greater populations, do not provide pre and posttest evaluative data, and require further replication and validation in order to determine effective engineering practices in a K-12 setting (Committee on K-12 Engineering Education, 2009). This is not to say that these assertions are wrong, but they do not have a body of evidence to support that they are correct.

Engineering and Engineering Practices.

The limitations listed above are important to keep in mind when discussing the tentativeness of the projected effective engineering pedagogical content knowledge (EPCK) needed by teachers for the understanding of engineering subject matter content and domain specific structures such as the engineering habits of mind; discerning students' engineering misconceptions and ways to remediate them; and specific engineering instructional methodologies such as the engineering design loop (Viiri, 2008).

Engineering as Inquiry. Currently, engineering in K-12 has a lack of identifiable, engineering *only* specific characteristics that provide conceptual boundaries of the domain knowledge. Engineering, as a discipline, includes a range of other domain areas, each with its own unique knowledge base, which are used to frame engineering thinking. Trying to discern a conceptual core is problematic and leads to the perception that engineering is actually an *application* of knowledge from other areas as opposed to being a discipline in and of itself (Custer, Daugherty & Meyer, 2010).

In engineering, scientific and mathematical principles are necessary knowledge components used in conjunction with technological knowledge. Each of these others have differing norms for the acceptance of assertions and evidence as well as different understandings about the nature, limits, and acquisition of knowledge (Daugherty, 2012). Key science concepts and some methods of science inquiry can be used as the theoretical and methodological foundation for some engineering designs, whereas core mathematical concepts and computational methods in analysis and modeling within the design process and technology and technological concepts can illustrate the outcomes and encourage the consideration of the impact of the engineering design features on society (Katehi et al., 2009b).

The differences between engineering and technology can be subtle. Similar to how engineering is based on science and mathematics, technology is rooted in science and engineering and concurrently is also a product and a process designed to solve problems through the development of a tool, delineating how the tool is used and maintained, and the effects that the tool has on society (International Technology Education Association, 2007; Karwowski, 2005). According to Cross (2001), technological design and technology designers specifically target the artificial world, "the human-made world of artefacts...the proposing of additions to and changes to the artificial world…so design knowledge is of and about the artificial world and how to contribute to the creation and maintenance of that world" (p. 5).

Teachers' EPCK is informed by an inferred understanding of how engineering literacy manifests within students. Sneider and Purzer defined engineering literacy as…

> the ability to solve problems and accomplish goals by applying the engineering design process—a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and accomplish goals. Students who are able to apply the engineering design process to new situations know how to define a solvable problem, generate and test potential solutions, and modify the design by making tradeoffs among multiple considerations in order to reach an optimal solution. Engineering literacy also involves understanding the mutually supportive relationship between science and engineering, and the ways in which engineers respond to the interests and needs of society and, in turn, affect society and the environment by bringing about technological change (National Assessment Governing Board, 2010, p. 8).

Engineering Design. Engineering design thinking has some parallels to scientific inquiry within science teaching. Dym's definition of engineering design as a "systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" is often quoted in the literature (Brophy et al., 2008, p. 372). What is significant about the engineering approach is its focus on meeting human needs and wants using practical, real world limitations.

Engineering Design Loop. Engineering design also is a rough correlate to scientific methodologies for the testing of solutions and gathering data. Massachusetts was the first state to adopt K-12 engineering standards in 2001. Their *Science and Technology/Engineering Curriculum Framework* stipulates an eight step engineering design loop.

1. Identify the need or problem.
2. Research the need or problem.
3. Develop possible solutions(s).
4. Select the best possible solutions(s).
5. Construct a prototype.
6. Test and evaluate the solution(s)
7. Communicate the solutions(s)
8. Redesign. (Massachusetts Department of Education, 2006, p. 84)

There are some noted similarities in the types of cognitive processes used in design thinking and science inquiry. Both deal with questions or problems that require exploration toward solutions. Both involve consideration of key variables and testing of data. The cognitive tools used to design the various procedures are also similar: analogical reasoning, use of inductive and deductive reasoning, brainstorming, visual representations and mental models, along with the evaluation and analysis of the results. Modeling, using mathematical, visual or physical representations is found in both science and engineering. Both design thinking and science inquiry involves creative thinking and an understanding of the role of failure in terms of students' understanding of the various processes (Daugherty, 2012 ; Lewis, 2006; National Academy of Engineering & National Reseach Council, 2009).

However, science inquiry focuses upon the theoretical understanding the nature of the natural phenomena at hand, while engineering design uses the predetermined scientific knowledge to solve practical problems. Scientific inquiry does make tradeoffs between various practical constraints to deal with the application of theory that engineering must consider (Lewis, 2006; National Research Council).

Design Challenges and Misapplications. Deriving authentic engineering design challenges requires strategic planning. Householder and Hailey (2012) characterize engineering design challenges as ill-defined problems that are solved using engineering practices and the integration of content and knowledge from science, mathematics and technology. The design component involves generating or altering objects or processes with the challenge for the learners to resolve the problem found within the designed context rather than a natural one.

According to the researchers' there are four areas that purport to be design challenges but are not: (1) within *science inquiry activities* whose purpose to have the learner gather evidence and understand core science theory in an event but not develop a product or process; (2) *problems within STEM textbooks* that have algorithmic procedures leading to a predetermined, and common, outcomes; and (3) *crafts activities* which do have unique solutions and are functional but do not involve the application of science or mathematics in the development of the final product. The fourth situation, *gadgeteering*, requires a special note particularly in terms of engineering within an elementary setting and the rigors required of the process.

> For a problem to be considered an authentic engineering design challenge, its solution must not be solely dependent upon tinkering, “gadgeteering,” or making random modifications without basing those changes upon mathematical and/or scientific analyses. An engineering design activity should be firmly grounded in principles from mathematics and science. Iterations of the design must be built upon a sound rationale and analyses of the data resulting from earlier trials rather than relying upon simple trial and error. Gadgeteering is often associated with the trial and error invention process, in which an inventor may tinker with alternative materials and procedures to find more workable solutions. The engineering design process involves understanding of the science undergirding physical relationships and the mathematical foundations of models that guide engineering design (Householder & Hailey, p. 16)

Engineering Habits of Mind. Engineering in K-12 Education (Committee on K-12 Engineering Education, 2009) outlined three major precepts for effective engineering in a pre-college setting: (1) needs a K-12 design focus, (2) combines mathematics, technology, and science within the content area, and (3) incorporates the engineering habits of mind. In the committee’s policy statement, the engineering habits of mind included the following elements: systems thinking, creativity, optimism, collaboration, communication, and ethical considerations. While most of the elements are straight forward, systems thinking, creativity, ethical considerations, and optimism require further defining. Systems thinking comes from the technological literacy domain and involves the consideration of how independent components (either natural or technological) can retain their own independent properties, behaviors, and functions yet work in interdependent and interactive ways to produce unexpected and unique outcomes that cannot be predicted by how each component parts function individually. Understanding the relational dynamic between the process, product, and result is the inherent goal of systems thinking (Katehi et al., 2009b; Lachapelle & Cunningham, 2014). Creativity, particularly in terms of problem posing and problem solving, is a core aspect of engineering habit of mind. Within a classroom, problems can either be well-structured or ill-structured, the former with its known outcomes and procedural methods to problem solving do not support creative problem posing while the latter, where novel solutions discovered by the learner do. "Future teachers must come to understand that creativity cannot be engendered by mere formula. …they will have to strive for the ideal of a classroom climate that encourages and supports deep thinking, risk taking, inquiring, information seeking, and question asking" (Lewis, Petrina & Hill, 1998, para. 77). Engineering is situated within a societal context, ethical considerations are an important aspect of engineering and technological design because of the possible impact, both negative and positive, on people and the environment. Optimism is the belief that solutions for problems are available and successfully implemented within a design challenge, which is a unique attitudinal disposition of engineering (Katehi et al., 2009b). Creativity, collaboration, and communication are shared elements between the engineering habits of mind and the NOS elements of science.

Misconceptions and Novice Characteristics. Similar to misconceptions in science, there is a noted correlation between the misconceptions and attitudes that teachers have toward engineering and technology and those held by their students (Hsu, Purzer & Cardella, 2011; Lambert et al., 2007). In many instances, teachers have a limited understanding of engineering and the design process and will often hold broad conceptualizations of engineering and low familiarity with both. According to Hsu et al., multiple studies in the United Kingdom and the United States found that teachers and students believe that engineering is primarily concerned with building and construction rather than including problem solving, planning, analysis, and reiterations (2011). If science and mathematics are the theoretical foundation for the learning objectives, then elementary teachers weak in these areas will have difficulty with the additional complexity of embedding them within an engineering design challenge and will be prone to exhibit the more didactic methodology of less expert teachers.

Elementary teachers exhibit a general lack of comfort for, and disinterest in, teaching mathematics and science, and exhibit even less so for engineering and technology (Cunningham & Hester, 2007). Given that engineering and technology are not required elements of preservice elementary certification, nor are they a long-term component of the established K-12 curriculum, elementary teachers are the least prepared to teach the subject (Lee & Strobel, 2014). School districts and their boards use standards to frame the formal, intentional curriculum that is the set of learnings to be taught in school through written, supported, taught, and tested elements. New standards bring noted changes to the formal curriculum. Consequently, professional development is the one of the institutionalized routes by which teachers gain the tools and resources needed to strengthen their subject specific PCK when changes in teacher educational practice are required (Glatthorn et al., 2009).

Integrated STEM and Professional Development

Educational innovations, as opposed to educational change, are disruptive forces. The institution and adoption of NGSS has the potential to be markedly disruptive if instituted to the degree that the policy makers desire. Elementary teachers, generally speaking, come ill prepared in their understanding of science, engineering, and technology content, nor do they have the pedagogical skills to feel confident about their teaching pedagogy in these subjects.

Lee and Strobel (2014) provide a convincing argument concerning the degree of adjustment teachers might have to make to bring integrated STEM into the classroom. Science inquiry, promoted in preservice classes and in professional development in the early part of this decade, had the advantage of making science and science inquiry a core subject in an elementary setting. Engineering and technology was not promoted in a similar fashion. Lee and Strobel, therefore, contend that there are four problems that will need to be considered when designing a elementary professional development courses: (1) that engineering and technology are new content domains for teachers; (2) the interplay between new and old content areas taught in the classroom will cause the older to transform substantively; (3) that elements of engineering and technology—such as modeling and engineering design—will be used in other ways within the older subject areas but will entail new pedagogical approaches; and (4) the integrated STEM is conjoined to reform movements which, in turn, influences the attitudes and beliefs of teachers towards engineering and technology into the classroom.

Professional development is the "comprehensive, sustained, and intensive approach to improving teachers' and principals' effectiveness in raising student achievement" (Wei et al., 2010). Unfortunately, the onset of the Great Recession in 2007 reduced funding for education at federal, state, and district level. So much so that, by 2008, teachers had fewer opportunities for sustained professional development—professional development that lasts more than eight hours—than teachers did four years prior. Instead, professional development tended to focus upon short-term workshops that had minimal influence upon teacher practice in the classroom. School districts chose to provide professional development mostly in the subjects that were tested annually or were tied to federal funding, like language arts and mathematics. (Buczynski & Hansen, 2010; Sneider & Purzer, 2014b; Wei et al., 2010).

In order to understand the scope of innovation required to successfully institute integrated STEM, and engineering and engineering practices in particular, framing the effective practices of professional development is worthwhile to note.

Professional development design characteristics. Historically, teacher development has been a notoriously tough sell. In Supovits and Turner's (2000) metaanalysis of professional development research of the l980s, every major work on the topic disparaged its effectiveness. In an included 1985 national survey, teachers ranked in-service training as their least effective source of learning. The researcher's attribute this negative attitude to professional development experiences that did not take into account teacher motivation and the developer's lack of insight into environmental and personal factors that affect the change process.

Teacher professional development, as defined by Little (1989), is any activity designed to improve the performance of roles that employed staff have currently or will have in the future. Unfortunately, there is currently no unified delivery system of professional development able to guarantee that all teachers end up with the same knowledge base. Professional development is a process of continuous negotiation on both the part of the facilitator and the participants, starting with the planning stage with matching curriculum to the anticipated needs and goals of the participants, while taking into consideration the requirements of the larger stakeholders within the school, district, and state. Negotiation happens during the delivery stage, where shifts in the learning flow and interactions between the people require modifications in the content, purpose, control of activities, and discourse style. Determining if professional development is successful is difficult as there is no standardized method to see if the multiple aspects that promote teacher learning are successful (Guskey, 1994; Wilson & Berne, 1999).

Teacher learning is highly situated and contextualized because of the high variance in educational contexts in which teaching takes place. Because of this, there can never be one right answer in terms of professional development delivery, but professional development design is the act of determining "a collection of answers, each specific to a context…thus finding the *optimal mix* ─ that assortment of professional development processes and technologies that will work best in a particular setting" for any given set of teaching professionals (Guskey, 1994). There are *some* identifiable constants, however, for effective professional development training that include the following: being job embedded with support for stakeholder's goals, practicality and applicability, active participation of participants in integrative (multi-formatted) activities, development of collegiality, and sustainability of support over a marked period (Fogarty, 2009; Hunzicker, 2011). Consequently, effective science, and by extension STEM, professional development contains the following:

> well-defined image of effective classroom learning and teaching, opportunities for teachers to build knowledge and skills, modeling the strategies teachers will use with students, building a learning community, supporting teachers as leaders, providing links to other parts of the education system, and providing for continuous assessment and improvement (Jeanpierre, Oberhauser & Freeman, 2005, p. 204).

Using both the general and domain specific elements of professional development design provides a useful frame for discussing professional development needs of the current elementary school teachers.

Building teachers' content knowledge and pedagogical content knowledge. Within the last decade, the idea of teacher learning progressions has taken a more developmental approach to teachers' career professional development. These progressions help a teacher move from a novice to a more expert stance through stages that are coherent, continuous and mediated by ongoing support and instruction. This is particularly important for teachers, in terms of learning how to create an effective learning environment with their students given the new expectations within science reform (Schneider & Plasman, 2011). Teachers are not able to teach content with which they themselves have not effectively grappled. An important element for teacher competency in teaching science is the depth and degree to which subject area content is integrated into the professional development itself (Heller, Shinohara, Miratrix, Hesketh &

Daehler, 2010). Professional development that models effective inquiry based strategies and carefully scaffolds the teachers' learning of the necessary mathematics and science content knowledge has been proven effective for transfer into the classroom (Buczynski & Hansen, 2010; Jeanpierre et al., 2005). Exposure to domain specific pedagogies that are specific, grade level appropriate, and matched to the appropriate standards have a better chance of being adopted by teachers (Buczynski & Hansen, 2010; Diefes-Dux, 2014; Lachapelle & Cunningham, 2014; Lee & Strobel, 2014).

Integration. Integrated curriculum, because of its student-centeredness, has had many well documented benefits for student learning as it is more stimulating, increases critical thinking skills and problem solving, and aids in student retention of subject matter (Stohlmann, Moore & Roehrig, 2012). Integrated STEM education is "a holistic approach that links the disciplines so that learning becomes connected, focused, meaningful, and relevant to the learners" through dealing with real world problems that cross disciplinary boundaries (Moore et al., 2014, pp. 38-39). Being able to effectively use STEM in the elementary classroom is inhibited by the teachers' lack of STEM and engineering PCK as well as the lack of effective understanding, modeling and training in integrative approaches (Roehrig, More, Wang, & Park, 2012). Huntley's (1998) integrative theoretical framework has been a standard way to define the different kinds of curricular integration. *Intradisciplinary* integration consists of units from only one discipline. The focus is upon exploring elements and topics that define and delineate core knowledge and/or practices of a single content domain. *Interdisciplinary* integration has one domain as the primary focus but other subjects are used to provide the context for, and aid in the learning, of the core domain. How the other subjects provide support, however, is not made explicit to students. In *integrated* approaches, the connection between and among disciplines is made explicit throughout the whole process to enable the students to understand how the elements of the various disciplines build and complement each other (Nargund-Joshi & Liu, 2013). Hinde further stipulates the effect of interdisciplinary and integrated curriculum for students as an approach, "that purposefully draws together knowledge, perspectives, and methods of inquiry from more than one discipline to develop a more powerful understanding of a central idea, issue, person, or event" (2005, p. 106).

Fogarty (2009) further sub-categorizes these three basic types along with a fourth category dealing with learner configuration that is not pertinent to this study and will not be used. Intradisciplinary integration is broken into cellular, connected, and nested integration. Cellular integration is the traditional model of retaining disciplines in silos. Connected integration happens within the subject domain where there is a building connection of topics with the explicit relating of ideas. Nested integration targets multiple skills (social, thinking, and content skills) based on the discipline standard. Interdisciplinary integration is subdivided into sequenced and shared integration. Sequenced integration involves teaching the separate domains but teaching them at the same time with similar ideas being taught in concert with each other. In shared integration, two disciplines are taught with overlapping concepts or ideas that are used as organizing criteria. Finally, fully integrated approaches can make use of webbed, threaded or integrated cross-disciplinary approaches. Webbed integration represents a conceptual thematic approach. Threaded approaches link key skills and ideas though a big idea that stretches across many disciplines. The integrated cross-disciplinary looks to find consistent patterns that run through all the disciplines and the content is taught via the patterns. Designing curriculum involves pedagogical decision making in terms of understanding which form of integration is appropriate for a given task. The three main integration categories, with their related sub-categories, may be better understood when shown together (Figure 2).

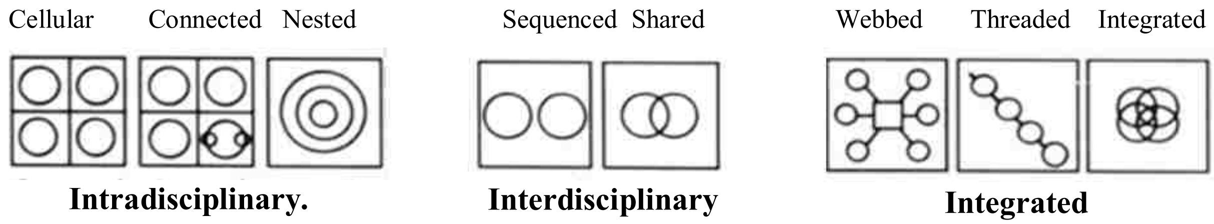


Figure 2. Integrated curriculum. Image adapted from Lake (2000). Portland: Oregon: Northwest Regional Educational Laboratory. Publication is in the public domain and may be reproduced and disseminated without permission but with the acknowledgement of NWREL as the developer.

Frykholm and Glasson (2005) warn that interdisciplinary integration in STEM makes the assumption that the teacher has the pedagogical content knowledge to understand how the disciplines are discrete from each other. For teachers new to STEM, this can be an unrealistic expectation. While the teachers might have some competencies in the various subjects, the parameters of the domains are still ill formed. Instead, the researchers argue a case for *connective* integration, where connections are made between the authentically situated practices of each of the fields and common to the learner. Speaking in regards to science and mathematics specifically, Frykhom and Glasson contend that teachers can identify and make “connections between mathematics and science that they see as intuitive and relevant. Rather than resting primarily within the construction of each discipline, the mathematics and science connections tend to emerge from the prerequisite knowledge bases and experience of teachers (p. 130). STEM education currently has little research to demonstrate how all four domains are interconnected and serve as foils for each other therefore using the connective approach seems to be a good first step in the integrative process (Katehi et al., 2009; Moore et al., 2014).

Educative curriculum materials and scaffolding. To foster learning, the structure of the materials used in the professional development must be "accurate, complete, and coherent in terms of content and effective in terms of pedagogy—with good representations of the content, a clear purpose for learning it, and multiple opportunities for [teachers and] learners to explain their ideas" (Davis & Krajcik, 2005, p. 3). As such, the educative curriculum materials used to promote teacher learning not only should help them make sense of the current STEM topic and methodology but must also help support the teachers' transfer of knowledge into their own classroom. Scaffolding of materials allows the teacher to focus on core aspects of the content and makes the task more manageable in terms of cognitive load, thus closing the divide between educator, theory, and the professional development.

Teacher constructed STEM materials. Constructing new curriculum and lessons can be overwhelming for a novice STEM teacher. Being able to access an appropriate systematic methodology for curriculum construction helps in terms of the following: teachers' understanding of the scope and sequence; selection of optimal activities that promote student learning and conceptual change; the selection of appropriate formative and summative assessments; and providing for the metacognitive reflection needful for teacher critical thinking and transfer of knowledge (Howard, 2007).

Effective integrated STEM engineering curriculum, according to Moore, Stohlmann, Wang, Tank, & Roehrig (2014) has six components: (1) it is engaging, personally motivating and provides a meaningful context for the learner; (2) has engineering design challenges that make an appropriate use of technology that engage students in problem-solving, creativity, and higher order thinking; (3) allows students to learn from failure and go through the redesign process for improvement; (4) has mathematics and/or science content as the main learning objectives that are obtained and improved through the use of engineering design to develop key technologies; (5) is delivered through student-centered methodologies such as inquiry or discovery learning; and (6) places a stress upon teamwork and communication.

Understanding by Design Curriculum Framework. One of the few well-established curricula for elementary teachers, Engineering is Elementary (EiE) is structured explicitly using Wiggins and McTighe's backwards design curriculum model. Cunningham and her staff at the Museum of Science in Boston purposely chose an intradisciplinary, threaded design approach by the pairing of science and engineering as the core STEM domains with connections to language arts, mathematics, and social studies. The EiE units involve the most common science topics taught in elementary schools. Each unit is grounded by the theory behind a single science topic, using the theory within a related field of engineering, and constructing a form of technology connected to the type of engineering within a spiraling, activity based learning unit framed by Enduring Understandings and Essential Questions (Cunningham, 2009).

Understanding by Design (UbD), developed by Grant Wiggins and Jay McTighe, centers on the backwards design. Here the key student learning outcomes, the *outputs*, are considered first in conjunction with the evidence needed to prove that learning has occurred. The selection of the activities and lessons, the *inputs*, are selected to help scaffold student knowledge. These learning outcomes are established through the curricular goals of the *taught* curriculum and by established content standards of the *formal*. Wiggins and McTighe reference constructivist thinking when they define understanding as "a mental construct, an abstraction made by the human mind to make sense of many different pieces of knowledge" and that evidence of understanding is how they can show what they know and can do (2005, p. 250).

Various cognitive processes to solve the problem. Student naïve conceptualizations, defined by Wiggins and McTighe as the mapping of a working idea in a plausible but incorrect way, and is addressed through built-in formative assessment within the scope of UbD curriculum (2009). Wiggins and McTighe plan for the maximization of Brunerian knowledge transfer through the construct of *big ideas*—ideas that provide a conceptual lens to the unit, provide breadth of meaning through connecting skills, experiences and content; point to the essential elements that lie at the heart of the content matter, require engagement and thought to uncover, and have great transferability to other situations over time. When speaking about big ideas, Bruner stated, “the more fundamental or basic the idea he [the student] has learned, almost by definition, the greater will be its breadth of applicability to new problems. That the idea is wide as well as powerful in applicability” (2009, p. 21). These big ideas are broken down into two sub-categories: (1) Essential Questions, which help the learner explore, uncover, and gain knowledge; and (2) Enduring Understandings, which are the large mental conceptualizations which are generalizable and transferable over time.

UbD supports the kind of open, problem-based thinking espoused by STEM reform. It also can provide the curricular framework and support needed by teachers when designing curriculum in a new content domain. Teachers with limited PCK in an area will often focus on the teaching activities, rather than the connection of concepts, or consideration of the core disciplinary natures of the content matter. They will often omit essential content aspects because they do not recognize, understand or see the import of them. The UbD requires that teachers provide a *context*, or the background knowledge students need to be able to do the unit, consider the *continuity* or connections between the current content and that which comes before and after, and think about the *pedagogical suspense* or the timing and flow of ideas throughout the unit (Guess-Newsome, 1999).

Organizational Barriers and Conduits for Teacher Change

Types of organizational change. Well known in organizational development fields, the power of personal values and willingness to change first and second order beliefs are drivers that have to be considered when starting any institutional reform. Chris Argyris, an organizational development theorist, asserted in *Overcoming Organizational Defenses* (Argyris, 1990), that people will initially opt for first order change where surface processes and procedures are changed or modified. These kinds of change do not challenge a person's inner value systems, expertise, and power bases. Nor does it upset institutional values, in terms of companies or systems, because this type of change is not as painful as it does not shift existing organizational structures. Second order change, however, is disruptive and conflicting, with winners and losers, and a loss of face and expertise. Second order change challenges what people hold as fundamental, visceral truths. People and organizations can have the required knowledge needed for systemic innovation but still not act in a way that produces deep innovation and change.

Professional development for reform at the teacher level should address teaching cultural norms and belief systems by framing collegial support, provided in appropriate ways and of sufficient duration, for deep intellectual, pedagogical change to occur. Teachers need to see changes in action, the effect on students, and witness the benefits it affords. (Putnam & Borko, 2000). By structuring the professional development appropriately, shifts in practice become more stable within the teachers' praxis via the valuing of the gained expertise by the individual and social affirmation by peers, which fosters needed teacher confidence in continuing the change process (Barnett & Hodson, 2001; Jeanpierre, 2007).

Identity and Communities of Practice. Designated identities, as discussed by Forbes and Davis, is "a function of [teachers] knowledge, beliefs, self-efficacy, and general dispositions toward teaching praxis and the evolution of these characteristics over time through classroom practice…are which are fundamentally intertwined with knowing and social membership." These roles are "institutionally sanctioned, defined by unique patterns of discourse, and reinforced by shared experiences between teachers," which are linked to the idealized teacher vision of who the individual wishes to become (2009, pp. 911-912). These designated identities are the conceptual maps that teachers use to guide instructional decisions and are the attitudinal filters they use to evaluate change within their pedagogical knowledge. Considering the match between professional development opportunities, which are connected emerging educational reforms, and teacher identity is of value, as the reforms require that teachers think and teach in ways that challenge their preexisting values and beliefs (Magnusson et al., 1999).

Communities of Practice. As described by Lave and Wenger (1991) , a community of practice is a group of people who share a concern or passion for something they do and learn to do better as they interact regularly. It is also a social learning system, in which the social context supports two ways of meaning making, the first though the active participation in the co-construction of knowledge with others within the same group. Novices move up through the ranks until they become experts, fostering expertise in those who follow, or until they choose to exit the community. Legitimate peripheral participation defines how novices first participate in a group and they then enter an inward bound trajectory as they become full participants and possibly masters.

The second way that people make meaning in communities of practice is through the production of "the physical and conceptual artifacts—words, tools, concepts, methods, stories, documents, links to resources, and other forms of reification—that reflect [the] shared experience and around which [they] organized [their] participation" (Wenger-Trayner, Fenton-O'Creevy, Hutchinson, Kubiak & Wenger-Trayner, 2014, p. 180). Communities of practice, as social learning systems, are increasingly being used as forms of professional development, which supports new ways of thinking about the design of learning opportunities and the role of educational institutions.

Organization, Accountability and Power-bases. Teachers come with predispositions towards learning prior to professional development training based on who is providing the training and how the participants were solicited. Teachers have very clear ideas on what kinds of knowledge and instruction are going to be of most use, and are generally looking for training that supports and adds to already existing frames of reference. Rarely do teachers enter into professional development with the explicit purpose of challenging their fundamental belief systems and professional identity (Wilson & Berne, 1999). In order to move people from first order to second order change mindsets, there are five factors that influence the effective performance of any learning group: the structure, knowledge, non-human resources, strategic positioning, human process, and the ability of all of these elements to be integrated into a whole (Hersey, Blanchard & Johnson, 2001).

The participants in professional development are loosely organized in two ways, either vertically or horizontally. In schools, horizontal grade level teams are rarely formed based on interest, personality, or worldview factors that influence the level of internal cohesiveness of the group. Vertical, topical, or curricular teams are often formed through principal assignment or solicitation, teacher volunteering, or by the shanghaiing of the unenthusiastic individual who draws the short straw by default assignment (Hersey et al., 2001).

Vertically structured learning groups have accountably aligned to traditional power structures and hierarchies. They tend to have a reporting, or evaluative, characteristic given the possible mix of administration, curriculum leaders, department heads, and teachers within the learning group's organization (Nilsen, 2011; van Driel et al., 2014). As such, accountability within the group is tied to the supervisory dynamic between administrator and teacher.

Horizontally structured learning groups, "associated with engagement in joint activities, negotiation of mutual relevance, standards of practice, peer recognition, identity and reputation, and commitment to collective learning" have social accountability within the group members rooted within the psychological drive to be respected, be seen by others as having expertise, and the ability to self-direct in a learning context (Wenger-Trayner et al., 2014, p. 18).

Facilitators, teacher leaders, and cultural norms. With the inception of No Child Left Behind in 2001, in conjunction with the dominance of the standards and accountability movement in education, the need for an increased instructional capacity in schools to improve student performance on the annual assessments increased the number of teachers serving as instructional coaches, curriculum writers, and professional developers. The intent being to help teachers, both in formal and informal ways, toward a reform in their educational practice (Donaldson et al., 2008).

It does not matter if the facilitator is an outside expert, a formally charged leader, or an informally recognized teacher leader, instituting reform challenges in the deeply embedded, cultural norms in education bolster retaining the status quo: (1) *egalitarianism*--all teachers deserve the same status and recognition regardless of performance or effectiveness; (2) *autonomy*--protection against unsolicited interventions by administration and peers with the preservation of teachers' right to choose what and how to teach, and (3) *seniority*—belief that the length of tenure bestows positional legitimacy (Donaldson et al., 2008).

Trust and credibility are central to any extended STEM professional development in order to promote systemic change. Credibility is built through *social influence*, "a change in the belief, attitude, or behavior of a person (the target of influence) which results from the action of another person (an influencing agent)" and uses *social power*, "the potential for such influence…to bring about such change using the resources available to him or her" through informational, reward, coercive, legitimate, expertise, and referent power (Raven, 2008, p. 1). While all six bases do promote change, sustainable teacher centered change, which fosters change of the second order, is promoted through legitimate, expertise, and referent power.

In STEM professional development situations, *expert power* is ceded when the teachers believe that the facilitator has superior insights or knowledge that is applicable to their teaching situation. This power base is linked to an *information power base* where the facilitator has persuasive reasons why using STEM pedagogy is better and more effective than what the teacher is currently using to facilitate student learning and effective implementation. The last power base, *referent power*, is where the teacher identifies with the facilitator on a personal, emotional, and pedagogical level and wants to model the facilitator in his or her own teaching situation (Raven, 2008).

Learning to be an effective facilitator for change and supporting teacher expertise, according to (Knight, 2011), involves seven different aspects: equality, choice, voice, reflection, dialogue, praxis, and reciprocity. *Equality* is professional learning that is done *with* teachers, rather than training done *to* teachers, through discussion and collective, equitable decision making. *Choice* is having learner freedom within a given structure while *voice* pertains to creating opportunities for teachers to express their point of view and honoring that within the learning context. *Reflection* is allowing time for reflecting by looking back, looking at, and looking ahead at praxis. *Authentic dialogue* starts with humility, being learner centered, and by the facilitators questioning of their own assumptions. This is done with respect and empathy, legitimizing the learner's right to their opinions. The conversations are open ended, give and take. *Praxis* means to apply their learning in their teaching as they are learning, while *reciprocity* means that the facilitators are learning, engaged in the task, and evolving within the community as much as the participants are.

Practice based professional development. Van Driel, Beijaard, & Verloop's research in *practice based* learning—echoing Wenger's social learning systems and reification—describes the process whereby teachers have the "opportunity to solve and grapple with authentic issues encountered in classrooms and schools…in order to enhance knowledge, skills and performance" by examining artifacts situated in classroom praxis (2014, p. 187). Analyzing student work with an eye toward understanding how the teachers interpret student learning can be a powerful source of teacher learning. Furthermore, observing master teachers teach and model lessons, with a critical and facilitated debrief, undergoing a cycle of formative lesson plan critiques, forming study groups based on curriculum development or core content topics are other sources of teacher learning. These types of professional learning situations, particularly when done using horizontal teams, tend to reduce the degree of resistance to change and innovation. It is particularly effective with teachers who share similar professional roles, but have different experiences within the school, as this increases the value of the group's sharing of knowledge, growth in confidence of all the participants, and an increased willingness to incorporate and try out ideas of others (van Driel et al., 2014).

Time and support. Duration encompasses both the span of the activity as well as the total number of hours spent (Desimone, 2009). Large-scale changes in teaching practice occur after 80 hours of professional development, and change in classroom culture after 160 hours (Supovitz & Turner, 2000). The span of sustained professional development with 30 to 100 contact hours spread out over 6 to 12 months, according to Yoon (2007), was found to have a positive relationship on student learning. Unfortunately, teachers who are currently participating in science professional development are participating far less often and in far more traditional situations (Pea & Wojnowski, 2014). The professional development is often in the form of teacher workshops which are criticized for ineffectiveness in increasing teacher knowledge and praxis due to a lack of sufficient time, purposeful activity, and content within the training (Garet, Porter, Desimone, Birman & Yoon, 2001).

Time, resources, and monies for professional development are factors. Generally, of the elementary teachers who took science professional development in 2012, only a third had the opportunity to try out and then discuss what they had learned. Depending on the elementary grade level, only 44% had substantial opportunity to examine classroom artifacts of learning. Fifty-five per cent of the science professional development took place during the school year with far less use of common planning time, teacher workdays, the use of substitute teachers, or through early or late start time for students. Only 17% of the schools offered one-on-one coaching in science and the mentors were most often principals or teacher leaders (Banilower et al., 2012).

In sum, in order to make professional development relevant and worthwhile for elementary teachers, it is important to understand the group’s unique and situated learning needs, particularly in terms of designing effective avenues by which the teachers can bolster their own understanding of STEM content, pedagogy, constructivist methodologies, and their abilities to transfer that into the classroom and the curriculum they write. By doing so, within a community of like learners, should bolster their personal self-efficacy required to make fundamental second order attitudinal changes necessary to teach the subjects effectively and build a sense of expertise, not only within the classroom but also within the eyes of their greater school community. Finding the optimal fit of professional development activities requires hands-on experience, cognitive scaffolding, trust in and a high level of creditability in both the process and the people providing the professional development, as well as having prolonged, reflective engagement with the topic in order to make the STEM and NGSS innovations stick.

The Next Generation Science Standards

The overarching goal of the Next Generation Science Standards (NGSS) is a coherent and rigorous science education for all students, enabling them to be critical consumers of science and attain the scientific literacy necessary to be informed citizens able to engage in public discourse and decision making on issues of science, engineering, and technology (Shelton, 2015).

Understanding the differences between NGSS and the current Arkansas K-8 Science Framework will help highlight what areas of pedagogical content knowledge support the elementary teachers need during professional development. A comparison of the two standards with reference to the type of standard, relative scope and sequence, required levels of critical thinking, and methods of evaluation, demonstrates the differences.

Table 2 provides a brief comparison of the two standards with reference to the type of standard, relative scope and sequence, required levels of critical thinking, and methods of evaluation.

Table 2

Comparison of NGSS and Arkansas K-8 Science Framework Elements

Characteristic	NGSS	Arkansas K-8 Science Frameworks
Developed by:	National Science Teachers Association, the American Association for the Advancement of Science, and Achieve, Inc. (NGSS, 2013). Designed for college, career and citizenship as well as to reflect real world applications and to model science in action.	Committee of Arkansas educators with input from the Arkansas Department of Higher Education, Arkansas Department of Workforce Education, and review of national and state standards. Current website says standards are used for college and career but no clear indication of rationale.
Forces	Driven by economics to provide an educated citizenry to function in a global economy.	Meets graduation requirements set by the state.
Structure	(1) Disciplinary Core Knowledge (physical science; life science; earth and space; and engineering, technology, and applications of science); (2) Crosscutting Concepts (integrative frameworks which cut across domains); (3) Practices (Science Inquiry and Engineering Design) and (4) NOS in its own band.	(1) Nature of Science (Scientific Inquiry, Science Process Skills, one small content strand using technology) and (2) Subject Knowledge (physical science, life science, physical science).
Outside Applications	Overt and live links to CCSS (ELA/Literacy and Math) at the bottom of each page that not only lists the specific standards that match the NGSS standard but, when the hyperlink is clicked, takes the reader directly to the appropriate page on the Common Core web site.	No overt links but some implied within the communication of ideas in writing and reading section.
Purpose	Not designed to be a linear, sequential curriculum but specifies what a student should know and do, and how to demonstrate understanding. Hypertext popups over key phrases provide clarifications of meaning. Clear progression of understandings K-12. Used for teachers to construct own curriculum.	A set of content standards expected to be mastered by the end of the school year. Has inclusive skills that build upon prior grade level along with a basic progression of skills.
Depth:	Limited number of core ideas that spiral.	A large range of skills. No unifying core concepts.
Thinking:	Sentence stems use verbs that stress higher critical levels of thinking (modeling, analyzing, designing…) which are intended to be used in multiple authentic ways over longer time periods.	Sentence stems use verbs that stress knowledge and comprehension levels of thinking (listening, recalling, defining…). No evidence of integration, type of instructional delivery, or time frame.
Testing:	Currently in development by individual states.	Arkansas

Note: All information concerning the NGSS standards was obtained from nextgenscience.org. Information concerning the Arkansas K-8 Science Curriculum Frameworks standards are from the Arkansas Department of Education http://www.arkansased.gov.

Inclusion of Engineering and Technology. NGSS standards integrate science, engineering, and to a lesser extent, technology. The National Research Council, in *A Framework for K-12 Science Educatio*n, which provided the conceptual frame for the NGSS in 2013, defined these subjects in a K-12 context:

> "Science" is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space and environmental sciences…We use the term "engineering" in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems. Likewise, we broadly use the term "technology" to include all types of human-made systems and processes—not in the limited sense often used in schools that equates technology with modern computational and communication devices. Technologies result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants (National Research Council, 2012, pp. 11-12).

Understanding the conceptual differences between the three areas is of import particularly in terms of helping teachers understand the interaction between the science, engineering, and technology. Science aims to describe and explain the natural world through observation and forming patterns. Patterns lead to mental formulation of laws and the development of theories to find relationships for the laws. Engineering, on the other hand, takes the scientific theories and laws—as they are—and designs physical systems to address practical real world needs (Katehi et al., 2009b; Rhodes & Schatble, 1989). Technologies are the tools that scientists, engineers and people in general use to do their work.

Being able to see the subtle but real differences in conducting a scientific inquiry versus using the engineering design loop is worthy in terms of content domain understandings. The focus of the engineering design loop is rooted in practical application of scientific knowledge to help individuals identify real world problems and then systematically solve them through defining the parameters and scope of the problem; brainstorming multiple solutions and weighing them against the constraints of the problem; testing, evaluating, and refining until the best solution to problem is obtained within the original parameters (NGSS Lead States, 2013).

However, the integration of engineering and engineering practices within the NGSS is not without flaws. In their critique of engineering representation within the 2012 NRC Frameworks and the NGSS, Cunningham and Carlsen (2014), argue that language used within the Framework implies that engineering functions as an application of science while engineering in the NGSS functions as a unique discipline. They further note that key concepts in science were described using nouns the core ideas of engineering employed verbs which made engineering "sound like activities, not concepts, principles or theories" (p. 198).

Types of Standards. Content standards, like the current Arkansas Science Frameworks, describe the baseline knowledge that students should have learned at a specific grade level and delineates the core content within each curricular discipline upon which the students will be tested. Performance standards, like the NGSS, incorporate content standards and expected levels of student work product and process, assessment and instruction. Delivery standards describe the conditions for learning under which content and performance standards will be taught (Collins, 1998). Assessment boundary statements and clarification statements are placed within the standard to help the teacher with the performance expectations of what students should be able to do at the end of instruction.

Practices. As mentioned earlier in the literature review, the NGSS standards are the intersection of three different components—*practices*, *disciplinary core ideas* and *crosscutting concepts*. (National Research Council, 2012) Practices within a standard describe the theoretical understandings and processes used by scientists while engineering practices involve the methods engineers use to design and build systems. The authors make note that rather than just saying teachers should use inquiry methods, they prefer to specify exactly what cognitive, social and physical inquiry practices the students should be doing (National Research Council, 2012). Table 3 highlights the complementary elements of the NGSS science and engineering practices.

Table 3
Science and Engineering Practices

Science Practices	Engineering Practices
Asks a question	Defines a problem
Develops explanations using models	Makes models/prototypes
Plans and carries out investigations to test a hypothesis	Plans and carries out an investigation to test the prototypes
Analyzes and interprets data	Analyzes data to compare prototypes
Uses math and computational thinking.	Uses math and computational thinking
Constructs explanations to explain results	Selects best solution based on criteria
Engages in argument to defend best explanation from evidence	Engages in argument to defend solution and redesign
Communicates results	Communicates best solution

Note: (National Research Council, 2012)

Disciplinary core ideas and crosscutting concepts. Disciplinary core ideas are defined as the essential domain knowledge students need. Developmental learning progressions in Earth and Space Sciences, Life Sciences, and Physical Sciences broken up into grade bands delineate a total of 38 different topics that build in depth and complexity over time (Achieve, 2013a). Crosscutting concepts are seven broad integrative big ideas and themes, like patterns or cause and effect, that span across all the domains of science and engineering at all grade levels with the intent to "help students deepen their understanding of the disciplinary core ideas and develop a coherent and scientifically based view of the world" (Achieve, 2013b, p. 1)

Compare the difference between NGSS fourth grade physical science fourth grade standard which deals with energy to the Arkansas K-8 Science Frameworks standard on the same topic. The NGSS earth science standard, 4-PS3-4, is as follows.

> Students who demonstrate understanding can apply scientific ideas to design, test and refine a device that converts energy from one form to another. [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound*.] (NGSS Lead States, 2013)

On the other hand, the Arkansas Science Frameworks content standards focus upon discrete content knowledge to show mastery of a topic. For example, K-8 Arkansas Science Framework Physical Science Standard 7: “Students shall demonstrate and apply knowledge of energy and transfer of energy using appropriate safety procedures, equipment and technology. PS.7.4.3. Construct simple circuits from circuit diagrams” (Arkansas Department of Education, 2014, pg.13). There is a difference in terms of expectations, depth of knowledge, and structured support for understanding between the two.

Helping Teachers Transition to NGSS through Professional Development

The steep cognitive load to learn the required science and engineering pedagogical content knowledge in the NGSS will require much time, patience, and strategic opportunities during professional development to make the content assessable. It is important that these aspects be considered when designing the training (Barnett & Hodson, 2001). However, there is also another emotional factors which need to be taken into consideration when designing professional development: teachers’ self-efficacy, personal efficacy, and feelings of inclusion within the learning community. High degrees of these three attitudinal factors have a direct connection to the amount of first and second order change a teacher is willing to attempt not only in learning new content and methodology but also applying it within the classroom.

Understanding teacher negative dispositions toward science. Elementary teachers tend, as a group, to hold negative attitudes toward science and their ability to teach it in the classroom. It is important to recognize how powerful these attitudinal dispositions are. Bandura's 1977 social-cognitive theory deals, in part, with a person's sense of self-efficacy toward a learning task and ability to self-regulate. Bandura defined s*elf-efficacy* as the personal belief about one's ability to be successful when undertaking a new or ambiguous task, while *self-regulation* is the learner's "proactive efforts to mobilize emotional, cognitive and environmental resources during learning and self-observation, judgment, and reaction to one's process" (Gredler, 2009, p. 350). Both these elements fold into the mental image a person has towards professional development.

Yeager and Dweck characterized *personal efficacy* as the implicit theories on the ability of human characteristics to change by providing rationales for why things happen in day-to-day life (2012). Thus, a person's mindset, or implicit theory, about the changeable nature of personality and intelligence has an effect upon the degree of resilience he or she will have when facing a stressful situation and the individual's attitudes toward the situation itself. A fixed mindset views intelligence as unchangeable and character traits as inherent and static. A growth mindset holds that intelligence can be developed and increased over time and personality traits can be modified. Like Bandura, a person's mindset shapes how an individual self-regulates the attitudes toward learning and learning tasks, the degree of effort extended to learning, and attitudes toward success or failure a person has. Fostering effective change in professional development requires growing positive associations and encouraging growth mindsets through carefully aligned activities that build a sense of success.

Warford, in his discussion of zones of proximal teacher development, contends that the negative attitudes elementary teachers bring to science can be partially attributed to language and acculturation issues in terms of adopting research based best practices as “teachers unfamiliar with the more powerful discourse of the academy are likely to feel alienated by it and unwilling to test and develop the theories carried by it in their own practice” (2011, p. 253). Compounding the feeling of alienation, teachers also feel excluded from the culture of science, in terms of not understanding the *objects* of the scientific culture—the physical tools and bodies of knowledge within the various science domains, but also from the *actions* of the culture—the norms of discourse, patterns of thought, and acceptable behaviors (Settlage & Southerland, 2007).

Negative beliefs, low sense of self-efficacy, fixed mindsets, and a perceived lack of inclusion in the community of scientists serve as real affective barriers to learning during professional development. Providing a supportive environment in which to build emotional, adaptive competencies within teachers is important as it allows teachers to accept new challenges and develop new habits of mind more readily. It engenders a greater tolerance for ambiguity while learning new skills and knowledge. Adaptive experts function as “intelligent novices” who are willing to struggle to learn new skills (Schneider & Plasman, 2011). While affective dispositions can be significant barriers, they are not the only things that need to be addressed when introducing the NGSS.

Understanding the context of the language. As mentioned earlier, there can be a strong disconnect between teacher, academic language, and necessary domain content knowledge. The NGSS are helpful in that they describe and explain core content within the clarification statements. However, the standards do not provide teachers support in contextualizing the difference in the common meaning of a word and the sometimes different scientific meaning. For example, the word *pinch* commonly means to grasp with a thumb and forefinger but in electrical engineering it means the compression of a conductor by a magnetic field which is produced by a strong electrical current. Consequently, the elementary teacher with a poor knowledge of science content and vocabulary will struggle to understand the standards and how they are to be applied.

Given that teachers are supposed to make pedagogical and instructional decisions based on their comprehension of the standards, they may not recognize what content is essential for effective implementation and learning in the classroom. As a result, they may dismiss, change, or leave out important parts. Helping teachers know what is important to keep requires targeted professional development in order to assure the meaningful application of the standards into their praxis (Schwarz et al., 2008).

Curricular integration. The NGSS require and expect the standards to be taught integratively. Many teachers approach each content area as a separate discipline, to be housed in discrete teaching silos within specific blocks of time, with few connections to any other discipline when teaching (Schneider & Plasman, 2011). Curriculum integration can take many different forms depending upon the teachers' beliefs concerning what constitutes effective teaching and the degree of the teachers' acceptance of a particular type of integration methodology. Depending on the application in the curriculum, the NGSS is at the very minimum, interdisciplinary integration. Elementary teachers will need professional support to restructure their approach to meet the requirements of NGSS. If the benchmark tests used to measure achievement remain focused on the demonstration of factual knowledge, teachers will be leery of curriculum integration due to the time it takes to prepare and teach the units and with fears about coverage of material (Kysilka, 1998).

Concerns and attitudes toward reform driven by standardized tests. The NGSS have formative, performance expectations built into each standard. For teachers who are not familiar with them, teaching to those performance expectations is going to require a shift in thinking in terms of evaluating their students, given the anticipated recalibration of expectations following the administration of the pilot run of the Partnership for Assessment of Readiness for College and Careers (PARCC) tests in Arkansas schools during the spring of 2015. High stakes tests, which are tied to NCLB and provide rewards or sanctions based on annual performance, have been the driving force for many teachers in terms of the structure and pacing of their lessons (Grissom, Nicholson-Crotty & Harrington, 2014). The current Arkansas Science Frameworks do have a fifth grade statewide science test but, as of now, NGSS has not been linked to a state test at the elementary level. Unfortunately, the constructivist methodologies that encourage deeper thinking and science inquiry will be seen to be at odds with preparing students for taking the current benchmark tests. (Brown, 1992) reported that teachers are hesitant to use innovative strategies—like cooperative learning or higher order thinking strategies in lieu of more traditional methods—because they feel that the traditional methods would better prepare the students for the state tests. The specific assessments for NGSS are several years in the future. Unfortunately, a number of teachers make the tested curriculum the de facto taught curriculum rather than the written curriculum of the intended science reforms (Porter et al., 2011). The year following Project Flight, the 2015-2016 school year, all Arkansas third through eighth grade student were tested using via *ACTaspire*, commercial tests that align to the CCSS and ACT, in ELA, math, and science (Assessment., 2015).

Meeting the needs of a diverse population. A central aspect of the NGSS standards is science for all, not science for the few. Science, as currently taught nationally, struggles to integrate the cultural values, practices, and knowledge store of linguistically and culturally diverse students. Part of the charge within the NGSS is have the standards implemented through a multicultural lens, wherein the science instruction and assessment is built around the affordances students of color and those of poverty culture and linguistic experiences bring in order to foster their success (Southerland, Smith, Sowell & Kittleson, 2007).

According to the National Center for Education Statistics (2013) , 21% of American students nationally are English Language Learners yet only 12% of the current teachers in the field have had any training in teaching science to this population of students. Being able to support student learning and have access to the more stringent academic language of science is needful in order to make science content accessible for all students. Lee (2005) , stresses the need for proper balance between “teacher-directed and student-initiated activities may depend on the degrees and types of continuity or discontinuity between science disciplines and students’ backgrounds, the extent of students’ experience with science disciplines, and the level of cognitive difficulty of science tasks” (p. 515). Unfortunately, benchmark testing in English/Language Arts and Mathematics asserts such a marked pressure that appropriate science instruction for these students is “often deemphasized relative to the urgent task of developing basic skills in literacy and numeracy” (Lee, 2005, p. 493)

With the NGSS focus on science inquiry, where challenging teachers or adult authority and the stress upon discussion or argumentation of evidence, in support of answers that the students develop on their own, can be highly discordant to some of the cultural norms of students with limited English proficiency as maintaining harmony within a peer group and with older adults is culturally appropriate (Lee, 2004; Settlage & Southerland, 2007). Implementing structured professional development that helps teachers learn how to differentiate, scaffold and support learning for these students is an important first step.

Conclusion

Robert Evans, author of *The Human Side of School Change: Reform, Resistance, and the Real-Life Problems of Innovation (1996)* , opines that changes in school culture are a prerequisite for any lasting structural changes. Implementation of STEM reform and NGSS standards within elementary classrooms will not be effective or long lasting unless foundational and near universal issues surrounding elementary teachers' knowledge of and approach to the four domains are addressed. Evans stresses the need to build *followership*, or educational leaders, and those who will have to implement the change will have to develop a clear sense of purpose and vision as well as foster a commitment to change that is active, engaged, and self-managing on the part of each individual. Professional development can make a difference by successfully scaffolding activities to address the foundational problems that elementary teachers tend to have with teaching STEM, by making it accessible and long-term, and by addressing teachers' core learning styles and needs within a community of learners. This engenders a cultural shift toward followership which will allow sensemaking of the structural changes regarding the different expectations of the NGSS, being able to decipher the text of the standards and learning how to integrate them with other subject domains. It encourages teachers to try the more expansive inquiry methods within a high stakes testing environment and with students with diverse learning needs. If the implementation of the NGSS is strategic in promoting a "widening out" model—where active participation and collaboration of all the stakeholders is equally encouraged and supported, then the NGSS standards and the STEM reform have the potential to be effectively adopted and sustained over time.

Chapter 3. Research Methodology

Chapter Three states the educational context and research methodology used for this mixed methods exploratory case study. The chapter outlines the primary research question and six subquestions, methods of data collection and data analysis, and the design limitations that occurred when studying the perspectives and approaches of elementary teachers new to integrated STEM content and pedagogical methods used when designing curriculum. The research had a specific focus on how engineering and engineering practices were integrated within the context of integrated STEM throughout the course of professional development training.

Research Design Overview.

Project Flight took place over the summer and fall of 2014 in a mid-sized school district in north Arkansas. Third through fifth grade teachers were selected from three elementary schools, chosen for each school's close proximity to the local regional airport which was the corporate partner for the professional development's Arkansas State Department of Education (ASDE) No Child Left Behind (NCLB) grant. Teachers were solicited for integrated STEM professional development training during the summer of 2014. The objectives of the training for the teachers, and designated by the pseudonym Project Flight, were the following: (1) work in collaborative grade level teams to plan and implement developmentally appropriate aviation-related STEM curricula; (2) develop grade level curriculum units using the Understanding by Design method; (3) explore and develop appropriate assessments; (4) integrate the NGSS, Arkansas Science K-8 Frameworks and the Common Core State Standards (CCSS) when designing the curriculum; and (5) teach the common grade level STEM integrated unit created by December of 2014. Each teacher received a stipend of $1500, sixty hours of Professional

Development Credit hours, as well as the supplies and materials provided during the training funded by the ADE NCLB educational grant.

The purpose of the professional development study, for the researchers, was to ascertain how intermediate grade teachers would incorporate new STEM curricula into standing curriculum within the classroom and study the effects of professional development and mentoring on the teachers' sense of STEM efficacy. As the graduate assistant, and one of the researchers in the training, the current research, and the dissertation topic, as an outgrowth of the original Project Flight line of research.

Demographics. The area served by the school district in which Project Flight took place has experienced a boom in population, growing 51% from 2000-2010 census (U.S. Census Bureau, 2015). In 2013, the school district had 20,000 students enrolled K-12 with 43% being English Language Learners (National Center for Educational Statistics, 2013). As such, the district met the NCLB high needs poverty criteria, which required that at least 10,000 families within the district or 20% of the children enrolled come from families who earn below the federal poverty line (Education., 2015). Table 4 shows the three Project Flight elementary schools, called by the pseudonyms of Northside, Westside and Eastside, shared some core demographic commonalities. The schools had approximately the same number of students, which included a large population of Hispanic and Pacific Islander children, in conjunction with a high percentage of students on free or reduced lunch (97%, 87% and 72% respectively).

Table 4
Demographic Information of the Three Schools Involved in Project Flight

School Demographics	Northside	Westside	Eastside
Total Number of Students	616	637	642
Type of School	Regular	Regular	Rural/Fringe
Gender: Male	316	328	347
Gender: Female	300	309	295
Free and Reduced Lunch	603	560	466
Hispanic	493	451	364
White	47	117	170
Black	5	16	22
American Indian/Alaska Native	0	1	1
Asian/Pacific Islander	68	42	77
Two or More Races	3	10	8

Note: The most current NCES enrollment standards are for the 2012-2013 school year. The designations of ethnicity are those used by the NCES. Regular denotes a public school by the NCES.

Twenty teachers applied for the Project Flight training, ten teachers at the fifth grade level, six at the fourth and four at the third. All the teachers were White and 18 were female. When compared to the NSSME (2012) demographics for elementary teachers, the Arkansan teachers had greater levels of advanced degrees, with 75% holding a master's degree compared to the national norm of 25%. Overall, the Project Flight teachers were more seasoned with 70% of the teachers having up to ten years' experience and the remaining 30% more than ten. Seventy- five percent of the participating teachers were generalists with the other 25% being mathematics and/or departmentalized elementary science teachers, a literacy teacher, or Gifted and Talented teachers. Table 5 categorizes the number of teachers by their level of educational standing and years of teaching at the time they underwent Project Flight.

Table 5
Project Flight Elementary Teacher Demographic Information

Demographics	**Teachers**
Years of Teaching: 0-5	8
Years of Teaching: 6-10	6
Years of Teaching: 7-15	2
Years of teaching: 16-20	3
Years of Teaching: 21-25	1
Education Level: BS/BA (no graduate hours)	5
Education Level: BS/BA (+ 3-15 graduate hours)	0
Education Level: BS/BA (+ 16 graduate hours)	0
Education Level: Masters	14
Education Level: Masters (+3-15 graduate hours)	0
Education Level: Masters (+16-30 graduate hours)	1

Structure of the professional development. Effective elementary science professional development requires challenging, clear goals connected to the situated needs of the participants. The training curriculum needs visible and direct coherence to district policies, goals, and state educational standards. The activities and lessons should support active, research-based learning by the participants and be of a long enough duration to allow for follow-up, feedback and continuity of message in order to support participants' reflection on praxis and sustain a collaborative community of practice amongst the members. Evaluative components, in terms of teacher and student gains resulting from the training, need to be embedded within the training (Loucks-Horsley, Stiles, Mundry, Love & Hewson, 2009).

Project Flight met these required qualifications for effective K-12 science professional development. Twenty teachers and three University of Arkansas researchers (two professors and one graduate student) met for 80 professional development contact hours—two weeks in June and one day of follow-up training both in October and in November. Meeting Monday through Thursday, during the consecutive two-week summer block, teachers developed integrated STEM content knowledge related to the various fields within aviation coupled with domain specific pedagogical content knowledge that included the new topics of engineering design thinking and engineering habits of mind. This was delivered through direct instruction and by cooperative design investigations that involved the construction of models of airplanes, hovercraft, loop planes and air balloons. All of these investigations were developmentally appropriate for the students in third through fifth grade and could be readily implemented by the teachers in their classrooms.

Concurrently to the integrated STEM training, the teachers received professional development in the Understanding by Design curriculum model. Teachers worked in grade level teams to apply their integrated STEM understandings to the construction of grade level integrated STEM curriculum grade level units that also incorporated the teacher's overall integrated STEM pedagogical content knowledge. Each grade level had one University of Arkansas researcher providing support and feedback during the unit construction process. The curriculum units were problem based and used the NGSS, Arkansas K-8 Science Framework, and CCSS standards. During the summer sessions, two experts in civil engineering and GPS/GIS technology provided detailed background knowledge about how those fields were used within aviation. In addition, the teachers went on a day long field trip to the local airport which included tours of the hangers and control tower, testing of aviation fuel, looking at a variety of aircraft up close, learning about airplane design and aspects of flight, as well as taking a short flight in a single engine airplane.

Project Flight met for eight hours on October 11, 2015. A lieutenant colonel in the University of Arkansas ROTC program provided content specific information about military aviation. Student and teacher misconceptions about science, specifically force and motion, were also addressed by the researchers during the first day of follow up training. In the afternoon, grade level work time was provided before the teams presented the working draft of their curriculum unit. The last day of professional development occurred on November 18, 2015. At this time, the teachers received training in designing complex instruction and the four finalized curriculum units and sample lessons developed by the teachers were shared. Before the end of the semester, all the units were taught in the classrooms with some of the teachers filming themselves teaching a lesson.

Evaluation of the professional development was both formative and summative. Pre and posttests, daily exit cards, unit checklists, classroom observation tools, and teacher efficacy measures were used to assess the progress of the participants. The Project Flight Final Evaluation Report, as required by the ADE NCLB grant, was submitted in December of 2015.

Arguments for a Mixed Methods Case Study

This research used a mixed methods exploratory, embedded QUAL[quan] case study design (Nastasi et al., 2010). Case studies, as a research strategy, empirically investigate a contemporary phenomenon in a real world context where discerning the variables influencing the boundaries between the context and phenomena tend to be blurry (Creswell, 2014; Yin, 2012). Specifically, "case study research is a qualitative approach in which the investigator explores a bounded system (a *case*) over time, through detailed, in-depth data collection involving *multiple sources of information*…and reports a *case description* and case-based themes" (Creswell, 2007, p. 73) emphasis in original). Using an instrumental case study to investigate the impact of Project Flight training on teacher perceptions was ideal for the development of a holistic understanding of the phenomena.

The study's embedded, sequential research methodology that was predominantly qualitative in nature. The primary focus on qualitative methods was strategic as doing so aided in capturing the many complex, socially constructed realities of the teachers involved in the professional development as well as ascertaining the subjective, value bound meanings teachers ascribed to their experiences (Hatch, 2002; Yilmaz, 2013). However, including the smaller quantitative data component provided a sense of the group's changes in attitudes and beliefs over time. Collecting different kinds of data engendered the capacity for complementary comparison of information and the reinforcement of evidence used to support researcher inferences. As such, this increased the accuracy of the insights, interpretations of the data, and bolstered the creditability of the findings (Collins, Onwuegbuzie & Sutton, 2006; Gorard & Taylor, 2004; Newby, 2014). The units of analysis for the research were the three grade levels found within the Project Flight professional development.

Triangulation and analysis of the archived quantitative and qualitative data from the 2014 training, as well as new data collected from semi-formal interviews in the spring of 2015, allowed for the required flexibility in inductive thinking to identify and conceptualize the themes and patterns within the case being explored (Yilmaz, 2013). The findings of this research are based on the triangulation and interpretation of these two different data sets.

Research Population and Research Questions

The subjects for this study were solicited from the 20 Project Flight teachers. Fourteen teachers responded and consequently formed the non-experimental, multi-stage convenience cluster sample. The participants in this study were drawn from a pool who originally self-selected to take the professional development from the three schools designated for training within all the elementary schools in the district (McMillan & Schumacher, 2010). Research questions in mixed methods designs often include one or more encompassing main questions that target the connections between the qualitative and quantitative elements of the study. The subquestions, consequently, can focus either on qualitative or quantitative methodologies (Tashakkori & Creswell, 2007). For this study, there was one main mixed methods research question and seven subquestions:

Main Research Question: Does professional development influence elementary teacher perceptions of the curriculum and instruction of integrated STEM engineering and engineering practices in a grade 3-5 setting?

- Subquestion 1 (QUAL): Does the impending implementation of the Next Generation Science Standards influence teacher perceptions about STEM within their classrooms?
- Subquestion 2 (QUAL): How do engineering and engineering practices manifest within a teacher constructed elementary STEM curriculum unit?
- Subquestion 3 (QUAL): When teachers are constructing STEM curriculum units during STEM professional development, what is the role of engineering in comparison to the STEM subject domains and how is engineering integrated within the unit design?
- Subquestion 4 (QUAL): Does STEM professional development and teaching the common STEM curriculum unit change individual teacher perceptions about how to integrate STEM domains?
- Subquestion 5 (QUAL): Does STEM professional development and teaching the common STEM curriculum unit change individual teacher perceptions about how to integrate engineering and engineering practices?

- Subquestion 6 (QUAL): What are the perceived conduits and barriers to effective integration of engineering and engineering practices within an elementary classroom?
- Subquestion 7 (QUAN): Was there a change in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum during the course of STEM professional development? The null and alternative hypothesis for Subquestion 7 are as follows:

Null hypothesis (H_0): Over the course of the STEM professional development, there is no significant difference, at the $p = .05$ level, in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum.

Alternative hypothesis (H_a): Over the course of the STEM professional development, there is a significant difference, at the $p = .05$ level, in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum.

Understanding how these discrete subquestions are rooted in the literature is best addressed in a graphic form. Note in Figure *3* that several questions are addressed within multiple sections. The questions have been truncated into key words for ease of viewing

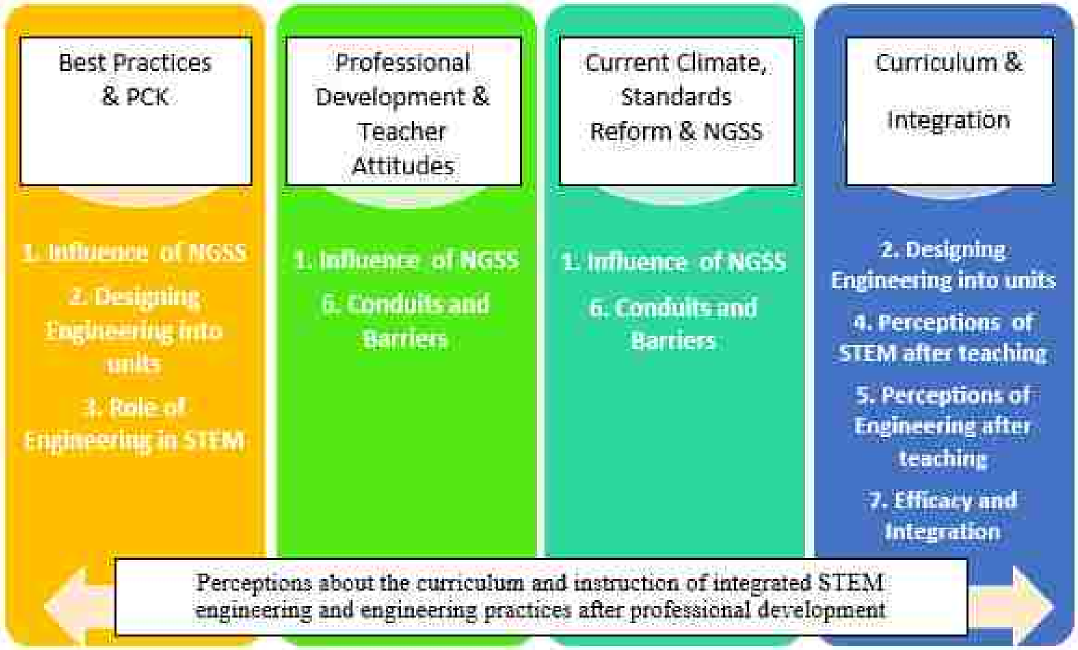


Figure 3. Relationship of Research Questions to Conceptual Framework

Theoretical Perspective and Role of the Researcher.

Social constructivists take the stance that absolute realities are unknowable, therefore the goal of research is to gain insights into how people understand and make sense of the world in which they live. Another goal is to understand the kinds of idiosyncratic meanings people ascribe to their experiences, meanings that are often directed towards certain objects or things (Creswell, 2014; Hatch, 2002). Meaning and the gaining of knowledge "takes place while participating in and contributing to the practices of the local community" and is mediated by the organizational features of the activities themselves (Cobb & Yackel, 1995, p. 19). Social and historical contexts frame lived experiences, therefore the researcher and the participants in the study co-construct a subjective reality of the phenomena that takes into account the effects of these experiences (Creswell, 2014; Hatch, 2002). When discussing qualitative research, Creswell affirms the use of open-ended questions as a method for the researcher to understand the participants' viewpoints on the situation being studied. It is important that the researcher be enmeshed within the context so that he or she may gather information personally. “The basic generation of meaning is always social, arising in and out of interaction with a human community. The process of qualitative research is largely inductive; the inquiry generates meaning from the data collected in the field” (Creswell, 2014, p. 9).

Consequently, I was the primary instrument for collecting and analyzing the data in this study. As the University of Arkansas graduate assistant in the 2015 Project Flight training when the archival data were collected, the initial researching role was that of *balanced participation* where participation in the activities was counterbalanced by times of observation. Doing so established a relationship and known identity with the members of Project Flight. However, for the 2015 data collection, the researching role shifted to that of a *participant as observer* as the primary function of the interviews was to gather information about teacher perceptions. Because the teachers knew that was the purpose of the interview, the teachers determined what they wanted to share and to what degree (Merriam, 2009).

Data Collection

Both archival and current data sets were used in the study. Archival data is primary source data which is collected prior to the start of a given research study and for purposes other than for which the data were originally collected in order to ask new questions, see comparisons over time, or draw evidence from different sources to provide a more comprehensive understanding of the phenomena (Corti, 2013). In qualitative research, archival data are frequently used when the intent is to describe and interpret the artifacts of a social group through the analytic approach of content analysis (Marshall & Rossman, 2006). In this study, the data collected during the course of Project Flight constituted the archival data set used for this study and, in doing so, were stripped of possible identifiers as required for its use (Sciences., 2012).

2014 archival data. Multiple sources of qualitative archival data were used for triangulation. In order to understand how integrated STEM, engineering, and engineering practices were introduced in the professional development, the following elements from the training were analyzed: the agendas, the training PowerPoints, handouts, photographs, as well as the Project Flight resources on Padlet.com. The use of photographs proved to be valuable in supplementing the written documentation by providing contextual information about how teachers approached the design challenges as well as supplying evidence for the sequencing of activities via the use of the photographic time stamps (Bogdan & Biklen, 1998; Prosser & Schwartz, 2003).

With regard to curriculum construction, and how STEM, engineering, and engineering practices were specifically integrated, the grade level curriculum units (one each for fifth and fourth grade and two for third grade), the teacher selected integrated STEM lesson plans and two grade level group presentations were used. Teacher perceptions were garnered from the qualitative comments from the exit cards and Question 9 and 10 of the Project Flight pre/posttests. The use of these artifacts were “tangible manifestations that describe[d] people’s experiences, knowledge, action and values” and as such their collection is a less intrusive way of obtaining quantitative data as the researcher doesn’t have to extract the data directly from the participants (McMillan & Schumacher, 2010, pp. 360-361).

Quantitative data were collected from three sources: Likert scale scores from the exit cards, from the Likert scale scores from the Question 9 and 10 of the Project Flight Pre/Posttests, and from four administrations of modified STEM-TEBI Form B survey of science teacher self-efficacy and outcome beliefs. Of the STEM-TEBI test, the first ten questions were used as these were consistent across all the STEM-TEBI administrations from the start and end of the summer session, the end of training in November, and the last administration of STEM-TEBI in June of 2015.

Using Bandura's social learning theory as a theoretical base, (Enoch & Riggs, 1990) developed the STEBI-B in order to measure in-service teacher self-efficacy and outcome expectancy beliefs regarding science teaching and learning, based on the assumption that having high levels in both served as required antecedents for teacher willingness to devote more time and energy to changing the science curriculum in the classroom. The STEBI-B comprises 25 questions, with 13 questions addressing science teaching efficacy and 12 addressing science teaching outcomes. The questions are framed using a 5-point Likert scale with answer choices ranging from *Strongly Agree, Agree, Uncertain, Disagree* and *Strongly Disagree* (Enoch & Riggs, 1990, p. 25). (Wenner, 2001) reported Markel's 1978 findings of construct validity and Riggs and Enoch 1990 factor analysis of stability and validity of the STEBI-B, reporting the results of the three longitudinal studies of science efficacy in preservice and in-service teachers, finding a Cronbach's alpha reliability correlations of .93, .92 and .86 (p. 183). Researchers from the University of Arkansas piloted a modified version of the STEBI-B modified for STEM and in which 'integrated STEM" was substituted for the word 'science' in each question, and renamed the test STEM-TEBI at an international STEM conference in 2013. The STEM-TEBI was used to gather information about teacher efficacy during the course of the Project Flight professional development.

2015 data collection. The 2015 data collection also made use of qualitative and quantitative instrumentation and was triangulated within and between each of the two data sets. Data were collected during the course of a three hour-long focus group semi-structured interviews, consisting of a recorded and transcribed interview responses, the researcher's field notes, the Think-Write-Share index cards, and curriculum documents consisting of the grade level *Understanding by Design* curriculum unit, a teacher self-selected lesson plan, and two sets of Think-Writes concerning engineering.

Semi-structured focus group interviews. Teachers were interviewed face to face in small focus groups by school, lasting just over an hour, with the Eastside and Westside teachers being interviewed on June 2, 2014. The Northside teachers were interviewed on June 3, 2015. Originally, there were to be two other fourth grade teachers participating in the interviews from Eastside but due to an extended illness and a week-long professional development conference they were not able to attend the focus group. Consequently, they were not included as part of the study. Project Flight Northside teachers were solicited via communication by their assistant-principal, through group emails by the researcher, and also by personal emails. However, only two teachers from Northside elected to join the study.

Interviewing the teachers in focus groups provided four affordances in terms of understanding the Project Flight teachers' perceptions. Doing so condensed the time it took to administer the interviews and provided better access to a greater number of teachers at the end of the school year before teachers dispersed for summer break. Using focus groups harnessed the grade level collaborative group structures of the professional development so that teachers within schools could speak to their common experiences with the training and teaching of their curriculum unit (Grudents-Schuck, Allen & Larson, 2004) state that the advantages of these social and semi-public conversations between participants and the researcher "elicit information that paints a portrait of combined local perspectives" while also providing a naturalistic setting in which the researcher can listen not only to the answers given but for the underlying "for emotions, ironies, contradictions, and tensions" in order to gather insights into the various groups' perceptions (p. 2). Using focus groups allowed for group-to-group validation of themes that were of interest to a number of participants between groups and which were also noted aspects of the discussions within each of the individual focus group interviews (Morgan, 2008).

Using a semi-structured interview process was also advantageous. After establishing rapport and establishing the facilitative role of the researcher, topics of significance to the teachers and to the research were introduced, which allowed the teachers to share their opinions, perceptions and attitudes. This format allowed for the intentional listening of the "special language and other clues that reveal meaning structures informants use to understand their worlds" (Hatch, 2002, p. 2). The order and topics of the questions, with additional prompts was predetermined to assure consistency in the interviews. However, the wording of the questions was open-end and conversational in tone allowing for flexibility in responses (Harrell & Bradley, 2009b; Merriam, 2009; Smith, 1995). This element of shared control over process allowed for tangents to be taken that brought to light unexpected aspects of the topic that were unanticipated by the researcher but important to the understanding the phenomena (Grudents-Schuck et al., 2004).

Use of the Think-Write-Share. Time granted to heighten awareness of thought processes, used to evaluate the effectiveness of personal choices made in the present as well as for projected long range outcomes, helps teachers' improve the quality of reflection about their own educational practice (Curwen, Miller, White-Smith & Calfee, 2010). The efficacy of using the Think-Write-Share method was three-fold. First, it allowed teachers the needed time during the interview process to gather their thoughts on complex topics. Second, it provided individual talking points to share within in the group setting. Third, it provided data which verified, expanded, and at times contradicted what the teachers shared with each other in a group setting which was could be mediated the social dynamics of the group.

Curriculum documents. In order to understand how teachers *currently* understood and perceived the role of integrated STEM and engineering and engineering practices within written integrated STEM curriculum, the teachers were asked to analyze their final curriculum unit and a self-selected lesson from the unit which exemplified what they considered to be their best integrated STEM lesson. The purpose of this activity within the focus group interviews was to crosscheck work product against teacher statements said within the interviews.

In the curriculum documents, the teachers were asked to highlight elements of engineering and engineering practices that were *present* in the documents and write comments on explaining their rationale. Teachers also wrote comments as to their perceptions of how engineering was *integrated* within each of the documents. Using the integrated STEM and engineering as their analytic foci helped illuminate the kinds of cognitive organizational schemas individual teachers used to recognize, differentiate, and select what they thought were the appropriate curricular elements (Harris, Mishra & Koehler, 2009).

In Table 6, the core questions for the semi-formal focus group interview are linked to the research questions of the study. Questions in italics are the Think-Write-Shares. The curriculum section is omitted in the table as there are no questions asked. However, this section provides information for subquestions 2 and 4.

Table 6

Relationship between Interview Questions and Qualitative Research Questions (RQ)

Interview Question	**RQ**
What kind of role do the science standards play in how you construct your curriculum?	1, 6
The Next Generation Science Standards are now being considered in the state legislature. How do you think the NGSS standards compare to the current Arkansas Science Frameworks?	1, 6
If you had to use the NGSS standards next year, would that change about how you would approach STEM your classroom?	1, 6
Think back over the Project Flight training that you received last summer and in the fall. What did you perceive to be the main objectives of the training?	2, 3, 4, 5
How did the professional development that you received influence your perceptions of STEM?	2, 3, 4, 5
What are your perceptions about the effectiveness of using the UbD model to write curriculum?	2, 3, 4, 5
Part of professional development is looking for an effective fit between teacher needs and provided training. If we could go back in time, knowing what you know now, what could be done to provide a best fit for you personally?	2, 3, 4, 5
What is your working definition of what it means to integrate curriculum?	2, 3
To your mind, what defines and characterizes engineering and engineering practices in the classroom?	2, 3, 4
What role does engineering play in relationship to the other STEM subjects?	2, 3, 4
Is there a difference in approach if you have to teach STEM in an integrated way?	2, 3, 4
What was your group's approach to integration when you were designing your common curriculum unit?	2, 3
When did your grade level teach the unit and over what period of time?	1, 3, 4, 5, 6
How did you, as a grade level, decide to implement the common unit?	1, 3, 4, 5, 6
Once you applied it in your own classroom, what happened?	1, 3, 4, 5, 6
Did teaching the unit change how you viewed integrating STEM and engineering within your classroom?	1, 3, 4, 5, 6
Now that you have taught the unit, imagine that the Next Generation Science have become the Arkansas standard. You have come back to redesign the curriculum unit to reflect what you now know about integrating engineering and engineering practices. What would your approach toward integration be this time around? What kinds of specific professional development would help you do so?	1, 3, 4, 5, 6

Note: The italics indicate questions that are used with the Think-Write-Share portions. Prompts have been left out. Curriculum material section have been excluded as there are no questions.

Quantitative data. Data concerning the changes of efficacy and length of professional development training were collected in three ways. Teacher perceptions of efficacy after a week of professional development were collected from the Likert scores of six days of summer exit cards given in June of 2014 (Appendix F).Longitudinal perceptions of efficacy were obtained from two sources. The first of these being garnered from four STEM-TEBI administrations, using the first 10 questions of the test, within a calendar year: (1) the pre-training test on June 9, 2014 prior to the start of the summer professional development; (2) Post1 on June 19, 2014 at the end of the summer professional development; (3) Post2 on November 8, 2015 approximately five months after the conclusion of the second follow up training day; and (4) Post3 on June 1, 2015 or June 2, 2015 nearly 12 months after the start of the original professional development training. The various tests were contrasted in SPSS, using repeated measures ANOVA, in order to gain an overall sense of efficacy of the teachers at the end of the professional development year.

The second source was three sets of Likert scale scores from Project Flight Pre/Posttest Questions 9 and 10 (Appendix G) concerning teachers' perceptions of their own familiarity with NGSS and implementation of STEM in the classroom and descriptive statistics and independent pairwise comparisons using SPSS were run. The questions were the following: (1) On a scale from 1-5 (with 1 being least familiar), how familiar are you with Next Generation Science Standards? and (2) On a scale from 1-5 (with 1 being least familiar), how familiar are you with implementing STEM (Science, Technology, Engineering, and Mathematics) in the classroom? The questions were administered on the following days: (1) the pre-training test on June 9, 2014 prior to the start of the summer professional development; (2) Post1 on June 19, 2014 at the end of the summer professional development; and (3) Post3 nearly 12 months afterwards on either June 1, 2015 or June 2, 2015 during the new data collection phase of this study. There was a

Pre/Post Test given during the first follow-up training day in October of 2014, but because names were missing on the majority of the tests, the data were not included.

Research Artifact Alignment with Research Questions

In sum, there were two phases for data collection in this research, those being archival data collected during the course of the Project Flight training and current data collected during the focus group interviews in June of 2015. Each data set had both qualitative and quantitative elements that were mapped to the subquestions of the main research question located in Table 7.

Table 7
Research Artifact Alignment with Research Subquestions

Research Subquestions	Archived Data	Current Data
1: Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within their classrooms? (Qualitative.)	• exit cards • Pre/Post Test • Project Final Report	• focus group interview • Think-Write-Share
2: How do engineering and engineering practices manifest within a teacher constructed elementary STEM curriculum unit? (Qualitative.)	• daily agendas • handouts • photographs • PowerPoints • Padlet • curriculum units • Project Final Report	• focus group interview • Think-Write-Share • curriculum unit • teacher STEM lesson
3: When teachers are constructing STEM curriculum units during STEM professional development, what is role of engineering in comparison to the STEM subject domains and how is engineering integrated within the unit design? (Qualitative.)	• daily agendas • handouts • PowerPoints • Padlet • photographs • curriculum units • Project Final Report	• focus group interview • Think-Write-Share • curriculum unit • Teacher STEM lesson
4: Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate STEM domains? (Qualitative.)		• focus group interview • Think-Write-Share • curriculum unit • teacher STEM lesson.
5: Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate engineering and engineering practices? (Qualitative.)		• focus group interview • Think-Write-Share • curriculum unit • teacher STEM lesson

Table 7 (Cont.)
Research Artifact Alignment with Research Subquestions

Research Subquestions	Archived Data	Current Data
6: What are the perceived conduits and barriers to effective integration of engineering and engineering practices within an elementary classroom? (Qualitative.)	• Project Final Report	• focus group interview • Think-Write-Share
7: Was there a change in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum during the course of STEM professional development? (Quantitative.)	• Pre/Post STEM-TEBI • Project Final Report • Exit Cards • Pre/Post Test • Questions 9 and 10	• Post-post STEM-TEBI • Pre/Post Test •Questions 9 and 10

Note: Main research question: Does professional development influence elementary teachers' perceptions of the curriculum and instruction of integrated STEM engineering and engineering practices in an elementary setting?

Validity and reliability during data collection phases. Qualitative construct validity during data collection phase required the accessing of multiple sources of evidence in order to create the necessary evidence needed for rich description, while external validity was garnered from the degree to which the methods connected to the broader research theory and methodologies (Yin, 2009). Multiple data sources were accessed in both data sets, all of which were tied to constructivist methodologies, in order to get a sense of the progression of understanding and perceptions the teachers had towards integrated STEM. Questions that were developed within the semi-formal interviews to measure areas specific to this research, such as perceptions of engineering practices and integration needed further internal reliability checks, and as such the questions were validated against the results of the interview portion of the research.

Research Procedures

Top down coding. Two different frameworks were used to conduct a top down *a priori* approach to the qualitative data found in the archival data: (1) the Committee on K-12 Engineering's (Katehi et al., 2009b) conceptualization of engineering in pre-college setting which included a design focus; mathematics or science as the theoretical foundation, and the engineering habits of mind (systems thinking, creativity, optimism, collaboration, communication, and ethical considerations) and (2) and Fogarty's (2009) *Continuum of Integrative Curriculum Types*, both of which were introduced in Chapter 2. A priori evokes prior theoretical foundations attributed to the phenomena which can come from the "characteristic of the phenomenon being studied; from already agreed on professional definitions found in literature reviews; from local, common sense constructs, from researchers' values, theoretical orientations and personal experiences" (Ryan & Bernard, 2003, p.88). Hermeneutic content analysis was applied to the data, during which the textual and multi-media data were broken into analytical units, which contained significant phrases or expressions relevant to the research questions, which were then coded according to the match to the requirements of the two frameworks (Bergman, 2010).

This was followed by looking for patterns, relationships, and themes within the data. Patterning required an investigation of the similarities, differences, sequences, or correspondences in the data, while relationships were the semantic understandings and themes derived from the process of integrating the discrete understandings into larger wholes (Hatch, 2002). Establishing an inquiry audit trail and documenting the decision making process, using an on-line Excel log, strengthened the dependability of the findings(McMillan & Schumacher, 2010). A discussion of a more specific process used for each of the archival core components follows below.

2014 Archival Data

Multiple sources of qualitative archival data were used for triangulation. Initially, in order to ascertain the scope and sequence of the Project Flight daily curriculum, the following elements from the training were analyzed: the agendas, the training PowerPoints, handouts, photographs, as well as the Project Flight resources on Padlet.com. The use of photographs proved to be valuable in supplementing data provided by the written documentation by providing contextual information about how teachers approached the design challenges as well as supplying evidence of the sequencing of activities via the use of the photographic time stamps (Bogdan & Biklen, 1998; Prosser & Schwartz, 2003).

Project Flight curriculum. Analyzing the Project Flight professional development curriculum and training materials, used to develop teachers' knowledge of integrated STEM pertaining to aeronautics and its application within the construction of a grade level UbD curriculum units, provided the educative context for how integrative STEM was contextualized and delivered to the teachers. The following professional development elements were analyzed: the scope and sequence of the professional development training; qualitative data from the exit cards administered at the end of the summer sessions; the individual grade level curriculum units and October's teacher selected STEM lessons. The quantitative data from the exit cards, STEM-TEBIs, and Pre and Posttest questionnaires was discussed earlier in the quantitative section of chapter.

Professional Development Scope and Sequence. The data funneled from large grain to small grain perspective. First, the training time spent on the two strands of professional development, integrated STEM and UbD, was delineated. Each strand was analyzed for percentage of time spent on different integrative forms used within the different professional development segments for each day. The integration forms were first sorted using (Huntley, 1998) intradisciplinary, interdisciplinary and integrated types and then further sub-divided using Fogarty (2009) sub-types (cellular, connected, nested, sequenced, shared, webbed, threaded, and integrated) which were subtypes within basic three.

Integrated STEM was further analyzed for evidence of the different kinds of STEM domains and how they were integrated. At this juncture, the decision was made to further modify the interdisciplinary level into two different forms to further clarify the relationship and interplay between the various content areas. The *dyad* form, which most closely adhered to Huntley's original, was applied when two domain areas were taught and valued equally throughout the individual sessions or when two domain areas were used but one domain played a greater role while the other area served in support. The *triad* form, new to this study, involved three content areas wherein a hierarchical relationship between three domain areas existed with two domains being in equal balance and a third serving in support or where one domain area was pre-dominate, a second supported, and the third played a minor role. To end, the total percentage of time spent on each of the STEM domain areas and integrative forms was determined.

Qualitative exit card data. Eight exit cards were given over the course of the Project Flight professional development, seven during the summer professional development training from June 9, 2014 to June 19, 2014, and one card given on the first fall training on October 11, 2014. All cards measured teacher self-perceptions of efficacy. Six out of the eight were members of a three paired set, the first in the series given Monday through Wednesday during the first week of the summer session and the second set the following week. Efficacy in applying the NGSS standards was queried on Monday, using STEM in the classrooms on Tuesday, and writing STEM lessons using UbD was asked on Wednesday. One exit card, given on the

Thursday of the first week, involved differentiation within a STEM classroom while the final October exit card asked Wednesday's question coupled with an inquiry about what the teachers would like to see during the final training. The qualitative data collected from the teachers' written comments were used to support the teachers' choice of the daily Leikert scale score.

There were three main phases undertaken in the qualitative analysis of the exit cards. First, the data were recorded in Excel and organized by exit card in order to conduct line-by-line content analysis. Themes emerged and were coded. Selective coding was done to compare the themes and their relationship to each other. Similar codes were grouped together and the frequencies charted. The themes were then coalesced into broad common catagories based on the connections or relationships between the themes within core groupings (Creswell, 2014).

Grade level curriculum units and teacher lesson plans. During the course of the professional development training, four curriculum units were developed. Third grade teachers divided into two groups, teachers from Eastside and those from Northside/Westside, and developed different curriculum units based on the same set of standards. The fourth and fifth grade teachers, from all three schools, developed a common curriculum unit per grade level. The first iteration of the units was developed by the end of the summer session on June 16, 2014. Modifications, due to additional professional development training, occurred during the first follow up session on October 11, 2014. The final and complete versions of the curriculum units were presented on the final day of professional development on November 8, 2014.

In order to examine teachers' perceptions of the NGSS, each unit's enduring understandings and essential questions were reported to contextually frame the unit, followed by an overview of the given standards and their connection to the core subject domains. Any missing standards, as indicated by the content of the lessons were noted, and the occurences of standards were tabulated by percentages of the total.

To understand the role of engineering and how it was integrated in comparison to other content domains, daily lesson plans or weekly lesson plans (the curriculum units of measure), were reviewed for the different content domains. Following that, the domains were categorized according to how they were integrated. Further clarification for each of the two steps follows.

Each lesson within the curriculum unit was reviewed for the purpose, objectives and procedures to determine what content areas were being represented. These, parenthetically, could differ from the Project Flight teacher's original STEM designations. If the lesson contained more than one content area, two things occurred. First, the degree to which the domain made up the lesson was determined, followed by ascertaining how the content areas functioned in relationship to each other. A content area could be the dominant STEM area, or used to support another content domain, or function within a minor capacity. Within the appropriate tables, these relationships were shown by the use of capitals for the dominant STEM content domain(s), lower case lettering for a supporting domain, and lowercase italics for content domains in minor roles. In order to determine ranking by importance, points were awarded. A point was given each time a content domain was the only or dominant subject within a lesson. If two content domains equally shared a lesson, each was awarded a point. No points were given for subjects in a supporting or minor role. These points were transferred into percentages and allowed for points of comparison of STEM content between all four curriculum units.

To determine the kind of integration were being used within the lesson, two steps were followed. First, categorization by basic integration form: intradisciplinary, interdisciplinary, or integrated (Huntley, 1998). If interdisciplinary, further categorization into two different forms was available, either the dyad or the triad. The specific sub-category of integration, using one of eight of Fogarty's (2009) integration types, was then assigned to ascertain the kind of curricular planning that involved and student outcome each type afforded. These too were compared across curriculum units.

To understand the specific role of engineering and engineering practices within each unit, teacher selected STEM lesson from the end of the summer session, the end performance assessment, and the rest of the remaining curriculum unit were studied to determine if engineering, as delineated by the Committee on K-12 Engineering Education (Katehi et al., 2009a) was represented as specific content domain or as a process of design. If the indicated curricular element did not meet the criteria for engineering, then that was discussed within the narrative with no determination made as to the type of engineering. Engineering practices in the form of the engineering habits of mind (systems thinking, creativity, optimism, collaboration, communication, and ethical considerations), due to their key importance as engineering dispositional world views, were discerned via line by line content analysis, tabulated, and explained in a narrative form for each of the three curriculum elements.

In sum, the archival quantitative data were analyzed using a hermeneutic a priori approach based on two frameworks applied to the scope and sequence of the Project Flight professional development training; qualitative data from the exit cards administered at the end of the summer sessions; the four individual grade level curriculum units and October's teacher selected STEM lessons.

Bottom up coding. Themes can also be induced by the researcher from empirical evidence (Ryan & Bernard, 2003). Qualitative analysis of the data from interviews began with transcription. The interviews were first read to get a general sense of the data and its meaning.

Moving from the specific to the general, inductive analysis began with an "examination of the particulars in the dates, looking for patterns across the individual observations, then arguing for those patterns as having the status of general explanatory statements" (Hatch, 2009, p. 161). Developing a frame of analysis, which functioned somewhat similar to the earlier units of analysis in the archival data, through line-by-line analysis of the interviews was important throughout the open coding process. Axial coding, which required the study of each category to ascertain a cumulative understanding of the relationships within that specific category, was done. Selective coding compared the themes and relationships across the various categories (Dooley, 2007). Narrative passages, which organized the themes according to research questions, included "subthemes, specific illustrations, multiple perspectives from individuals, and quotations" in order to understand the perspectives of the Project Flight participants (Creswell, 2014, p. 200). A discussion of a more specific process used for each of the 2015 data core elements follows below.

Interviews. Narrative passages, which organized the themes according to research questions, included "subthemes, specific illustrations, multiple perspectives from individuals, and quotations" in order to understand the perspectives of the Project Flight participants (Creswell, 2014, p. 200). While teachers were interviewed in mixed grade level focus groups, the themes were derived across schools and grade levels with grade or teacher specific exemplars being reported afterwards.

Interview Think-Write-Shares. Written qualitative data were collected during the course of the interviews using Think-Write-Shares (TWS). TWS prompts were given orally and the teachers were given a few minutes to jot down their comments on numbered index cards.

Aside from the prompt, no other instruction as to the kind and organization of the response was given. The index cards were collected at the end of the interview.

There were three main phases in the qualitative analysis of each of the TWSs. Individual teacher TWS were entered into an Excel spreadsheet, from the index cards, in order to do line-by-line content analysis. As themes emerged, they were coded and then subjected to comparitive selective coding to see the relationships between the different themes. Similar themes were grouped together and the resulting frequencies were reported in six tables along with supporting quotes.

Curriculum units, lesson plans, and Think-Writes. The process used for the 2015 curriculum data and lesson plans followed the same process used in the engineering and engineering practices section of the archival data in order to allow for a comparison between the two sets of data. The Think-Writes were entered into an Excel chart and the quotes used to explain and support inferences drawn from the other two elements. Like earlier section, the data were tabulated and explained in a narrative form for each of the three curriculum elements.

In sum, the current 2015 data were analyzed using a bottom up inductive analysis coding process to generate broad themes of teacher perceptions of integrated STEM, engineering, and engineering practices within the three focus group interviews, the Think-Write-Shares, as well as the curriculum units, teacher selected lesson plans and the two Think-Shares associated with engineering.

Quantitative Testing

Three different sources of quantitative data were collected over the course of 11 months to note changes in efficacy across the span of the professional development, and into the second semester of 2014-2015 school year, using the archival summer training exit cards, two Question

9 and 10 Pre-Posttest responses, and three STEM-TEBI administrations. These were coupled with quantitative data collected during the 2015 interviews which consisted of two other administrations of the STEM-TEBI and Question 9 and 10 Pre-Posttest queries.

Summer Exit Cards. Three sets of paired exit cards were used for statistical analysis of Likert scores of the study's 14 participants. Due to missing data cards within individual sets, descriptive statistics and unpaired two tailed *t*-tests with a significance level of $p < .05$ were performed on the exit cards using SPSS with the first exit slip in each of the sets serving as the pretest, and the second set as the posttest, in order to uncover if there were any statistical differences in teachers' confidence levels concerning NGSS, application of STEM in the classroom, and writing STEM lessons using UbD.

STEM-TEBI. The four administrations of the STEM-TEBI were contrasted using repeated measures ANOVA, using pairwise comparisons, to determine the F values and significance to the $p < .05$ level between the four administrations regarding teachers' perceptions of self-efficacy in STEM.

Question 9 and Question 10. The Likert scale scores from the three administrations of the questions were analyzed using descriptive statistics and independent pairwise comparisons using SPSS to see if there was a statistical difference to the $p < .05$ level in teachers' familiarity with NGSS and implementation of STEM in the classroom due to professional development over time.

All three sources of quantitative data results were presented in narrative form along with tables and figures displaying the descriptive statistics and respective standard errors of the means on either bar charts or line graphs.

Mixed Methods Data Analysis Procedures

The purpose of the mixed methods analysis at this stage was triangulation of the non-cross over data analysis of the 2014 archived data, the 2015 qualitative data, and the 2015 quantitative data. The triangulation sought to uncover the convergence and corroboration of results between the quantitative and qualitative data (Bryman, 2006). Regarding this study, triangulation was achieved through data integration, in which the broad findings of all three data sets were combined to form a coherent, synergistic new set of understandings (Onwuegbuzie, Leech & Collins, 2010). Through analytic generalization, these broad themes were applied to the teachers as a whole and then to the grade levels. The intent being to understand the extent that professional development influenced the teachers' perceptions of the curriculum and instruction of integrated STEM and engineering and engineering practices in an elementary setting, the implications of which can hopefully be applied in other, similar Arkansas schools.

Ethical Considerations of Human Subjects

The research followed the guidelines stipulated by the National Institutes of Health and the University of Arkansas Institutional Review Board for the consideration of human subjects. All the responses have remained confidential and the data kept on hard drives encrypted with BitLocker, a full-disk encryption technology. The drives were backed up using SpiderOak, a computer program that synchronizes, encrypts, and decrypts all data on the local computer before transmission so that the receiving server cannot extract the data or its content knowledge of the content of the data, as the encryption key remained locally stored.

The interviews involved recording the meeting. The face to face focus group interviews were recorded using a Tascam DR-05 portable digital recorder. The files were uploaded to the computer in an MP3 format. Only the transcriptionist and I had access to the recordings, and the transcriptionist interviews only after any of the identifying information had been altered to retain anonymity of the participants. The pseudonyms for the participants were derived from the top 14 most common names in the United States, according to the 2000 US Census, which precluded any names that would indicate a specific ethnic background and was not already a real surname of a teacher. Participant 1, Ms. Smith, received the most common name while Participant 14, Ms. White, receive the twenty-second most common name (U.S. Census Bureau, 2000).

The questions in the interview dealt with professional actions and perceptions. As such, they did not reveal any embarrassing data. The participants were required to verbally give their informed consent at the start of the interview and were required to sign the informed consent form.

Limitations, Delimitation, and Assumptions of the Research

This study has several limitations, the first being the choice to use a case study methodology because of the potential for researcher bias and subjectivity (Yin, 2009; 2012) Second, as a participant observer during part of the professional development training, researcher interactions with the teachers could have influenced some of their behaviors. Third, the teachers were recruited from an already small, self-selected cluster sample are less representative of and generalizable to elementary teachers as a whole (McMillan & Schumacher, 2010). Fourth, the timing of the focus group interviews at the end of the year proved to be problematic in recruiting teachers from one of the schools. Fifth, during the interviews themselves, the group dynamics and levels of acquaintance played a part in how and what information was shared (Harrell & Bradley, 2009a). Sixth, the archival data were inconsistent regarding how some of the original quantitative data were collected as well as requiring some researcher reconstruction of the situated meaning of a few of the original documents (Hammersley, 1997; Mauthner et al., 1998).

Seventh, the coding and subsequent themes were not independently coded by another rater during the course of an inquiry audit (McMillan & Schumacher, 2010).

A delimitation of the study was not to include students, student perceptions or student learning outcomes. While discussion about students will occur within the context of the teachers' conversations of their perceptions of teaching the unit, obtaining permission to use students was deemed too cumbersome and outside the core intent of the research. Two assumptions informed this study. The first is that teachers' implementation of the common grade level curriculum unit would differ in order to meet the situated needs of their students as well as reflecting the teachers own level of pedagogical content knowledge of the curriculum. The second assumption was that were unknown forces at work which influenced teachers outside the scope of the professional development which will have an influence the teachers' perceptions of the research topics. The use of the semi-structured interviews was used to help uncover and frame what these were.

Summary

In order to better understand teacher perceptions about integrated STEM, engineering, and engineering practices after professional development training and the subsequent teaching of the unit in the fall of 2014, this exploratory mixed methods case study triangulated archival data collected in 2014 with that of the semi-structured interviews conducted in June of 2015.

Chapter 4. Results

Research Study Overview

Twenty teachers in grades 3-5 from three elementary schools within the same Northern Arkansas school district, took part in Project Flight. The purpose of this integrated STEM professional development, for the teachers, was to learn integrated STEM content related to aviation and to write grade level curriculum units based on the topics presented during the two weeks of summer training in 2014 through two follow up training Saturdays during the 2014-2015 school year. Of those, 14 teachers volunteered for the study whose purpose was to discover the perceptions and integrative approaches that teachers unfamiliar with engineering and engineering practices took when designing a new curriculum unit of integrated STEM professional development and during the subsequent teaching of the unit. The intent was to determine other delivery methods of integrated STEM professional development and professional support to help Arkansas elementary teachers transition into using the NGSS standards which are slated to begin implementation in Arkansas during the 2016-2017 school year.

The research used a mixed methods exploratory, embedded QUAL[quan] case study design (Nastasi et al., 2010) in which 14 teachers opted to become non-experimental, multi-stage convenience cluster sample. Archival data from Project Flight and current data formed two data sets that were triangulated in order to discern the teachers' perceptions about the main mixed method research question and the seven subquestions which are listed below.

The overarching mixed methods research question is: Does professional development influence elementary teachers' perceptions of the curriculum and instruction of integrated STEM engineering and engineering practices in a 3-5 grade level setting?

- Subquestion 1 (QUAL): Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within their classrooms?
- Subquestion 2 (QUAL): How do engineering and engineering practices manifest within a teacher constructed elementary STEM curriculum unit?
- Subquestion 3 (QUAL): When teachers are constructing STEM curriculum units during STEM professional development, what is the role of engineering in comparison to the STEM subject domains and how is engineering integrated within the unit design?
- Subquestion 4 (QUAL): Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate STEM domains?
- Subquestion 5 (QUAL): Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about how to integrate engineering and engineering practices?
- Subquestion 6 (QUAL): What are the perceived conduits and barriers to effective integration of engineering and engineering practices within an elementary classroom?
- Subquestion 7 (QUAN): Is there a change in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum during the course of STEM professional development?

Professional Development.

Three of the qualitative research subquestions were directly tied to the professional development training the teachers received. The questions were:

(1) Research Subquestion 3: When teachers are contructing STEM curriculum units during STEM professional development, what is the role of engineering in comparison to the STEM subject domains and how is engineering integrated within the unit design?

(2) Research Subquestion 4: Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate STEM domains?

(3) Research Subquestion 5: Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate engineering and engineering practices?

Summer professional development for Project Flight occurred for eight days from June 11, 2014 to June 19, 2014. Two Saturday trainings occurred on October 11, 2014 and on November 8, 2014. The educative curriculum and training were intended to enhance teachers' pedagogical content knowledge of integrated STEM with aviation as the focus. The two broad professional development delivery strands, STEM and UbD were further reduced into six distinct subcategories.

Within the STEM strand, teachers' subject matter content knowledge in terms of the teachers' *content, syntactical*, *and structural knowledge* of the general characteristics of STEM, as a whole, and of the four specific domains found within STEM umbrella were addressed. The teachers' *syntactical* content knowledge, which is the knowledge of the rules which guide inquiry within the domain and delineate how new knowledge and evidence are to be evaluated (Shulman, 1986) was supported by presentations concerning the history and structure of integrated STEM and about the nature of science.

Content and *substantive* knowledge, or teacher knowledge of the core understandings, concepts, ideas of a specific domain area and how they are organized (Grossman et al., 1989) were developed via direct instruction, hands-on science investigations and engineering design challenges, and by outside experts in civil engineering, geoscience, and military aviation. These experts provided targeted instruction and expertise in their related fields as well as illuminating the real world applications to aviation.

This integration of various STEM fields' content and substantive elements were further enriched by a day-long field trip to the local airport, in which various aviation professionals (the pilot, air traffic controller, safety manager, and flight manager) developed learning stations for the teachers connecting the functions of the airport to the STEM fields.

Teachers' STEM pedagogical content knowledge, in terms of *specific instructional strategies* involving science inquiry, engineering, and engineering practices were delivered along with *learner and learning* sessions on the NGSS standards, how to address the needs of the English Language Learner in science, and differentiation within the STEM classrooms.

Curricular content knowledge, or the understanding of teaching materials and programs (Shulman, 1986) was bolstered by the direct training in UbD and the consequent application of that training by grade level groups in developing four aviation units. Reference Appendix I, Professional Development Curricular Sequence, for a day by day outline of the professional development sessions and the time taken for each session.

Character of the Professional Development Training. Establishing the integrative nature of the Project Flight professional development was needed in order to provide a foundation for understanding the teachers' perceptions of integrated STEM, engineering, and engineering practices. The five tables are sequenced from the basic integration of the two strands of professional development to the integration of specific content domains within STEM. Table 8 shows the minutes spent on training in STEM and UbD per day. Table 9 and Table 10, concerning the STEM and UbD respectively, denote the kind of integration found within the two different training strands. Table 11 illustrates how the different STEM content was combined and integrated within the STEM strand while Table 12 ranks the content integration by the percentage of time out of 1485 minutes of professional development spent on content development with the teachers.

In determining the form of integration, the individual professional development sessions when through three phases of categorization. First, they were sorted using intradisciplinary, interdisciplinary and integrated types (Huntley, 1998). Then, further sub-divided using Fogarty's (2009) sub-types (cellular, connected, nested, sequenced, shared, webbed, threaded, and integrated). It is important to note that the reporting of the various STEM content domains was further modified at the interdisciplinary level into two different forms provide more clarity about the structure and relationship between the content areas.

The *dyad* form, which aligned most closely to Huntley's original definition, was applied to two domain areas that were taught and valued equally throughout the individual sessions or two domain areas where one domain played a greater role and the other area served in support. The *triad* form, new to this study, concerns the involvement of three domain areas in which a hierarchical relationship existed with two content areas being of equal weight and a third offering support or in situations where one domain area was predominating, a second supported, and the third played a minor role.

Table 8 delineates the overall and daily balance between STEM and UbD instruction and provides data concerning the time spent on the two strands of professional development over the ten days of training.

Table 8
Minutes of Targeted Professional Development Spent Per Day on Research Areas

Activities	**D 1**	**D 2**	**D 3**	**D 4**	**D 5**	**D 6**	**D 7**	**D 8**	**O**	**N**	**Total**
STEM	135	135	175	180	355	190	210	150	195	0	1725
UbD	105	105	105	90	20	75	45	105	65	255	970
Daily Totals	240	240	280	270	375	265	255	255	260	255	2695

Note: D=Day. O=October. N=November. Minutes excludes time spent per day on professional development aspects not directly tied to research areas of study.

Overall, roughly two-thirds, or 64.00 %, of the professional development time was spent developing teachers' domain content knowledge through STEM related activities and the remaining third, or 36%, was spent on UbD. However, this overall ratio was not reflective of the daily norm. After the first three days, where the STEM instruction took up 56% or 62 % of the daily total, the amount of spent on STEM related activities was actually beyond 66% mark on all of the days but two. The balance tipped more towards UbD on Day 8 and on the last day of training in November. Here, the grade level groups prepared and shared their units either as unit drafts or the final unit.

Table 9 and Table 10 provide data about the kind of integration that occurred within the discrete professional development segments for the STEM and UbD strands. Both STEM content and pedagogical sessions were analyzed for their integrative type within Table 9 while UbD direct instruction and group curriculum construction sessions were considered in Table 10.

Table 9

Minutes of STEM Curricular Integration by Activity per Day

Integration	**D 1**	**D 2**	**D 3**	**D 4**	**D 5**	**D 6**	**D 7**	**D 8**	**O**	**N**	**Total**
Intradisciplinary											
Cellular	135	0	30	0	0	0	120	0	15	0	300
Connected	0	0	0	45	0	0	90	30	60	0	225
Nested	0	0	0	0	0	0	0	0	0	0	0
Interdisciplinary											
Sequenced	0	0	0	135	0	70	0	60	0	0	265
Shared	0	0	0	0	0	120	0	0	120	0	240
Integrated											
Webbed	0	135	145	0	355	0	0	60	0	0	695
Threaded	0	0	0	0	0	0	0	0	0	0	0
Integrated	0	0	0	0	0	0	0	0	0	0	0
Daily Totals	135	135	175	180	355	190	210	150	195	0	1725

Note: D=Day. O=October. N=November. Excludes time spent per day on professional development aspects not directly tied to research areas of study.

Twenty-three percent of all the professional development time was devoted to outside experts. The field trip and two of the expert sessions used fully integrated STEM content training (20.5%), while one expert session was delivered interdisciplinary (2.5%). The design challenges, tied to the science and engineering practices, comprised 20% of the total professional development time and were delivered through intradisciplinary (10.5%), interdisciplinary (4.5%), and fully integrated (5%) forms. All the rest of the STEM content and pedagogical sessions (21%), were delivered mostly through intradisciplinary (14%), or interdisciplinary (7%) means. All percentages have been rounded to the nearest half percent.

Table 10
Minutes of UbD Curricular Integration by Activity per Day

Integration	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	O	N	Totals
Intradisciplinary											
Cellular	45	0	0	0	0	0	0	0	0	0	45
Connected	0	0	0	0	20	75	0	0	45	0	140
Nested	0	0	0	0	0	0	45	0	0	0	45
Interdisciplinary											
Sequenced	0	0	0	0	0	0	0	0	20	195	215
Shared	0	0	0	0	0	0	0	0	0	60	60
Integrated											
Webbed	60	105	105	90	0	0	0	105	0	0	465
Threaded	0	0	0	0	0	0	0	0	0	0	0
Integrated	0	0	0	0	0	0	0	0	0	0	0
Daily Totals	105	105	105	90	20	75	45	105	65	255	970

Note: D=Day. O=October. N=November. Excludes time spent per day on professional development aspects not directly tied to research areas of study.

Seventeen percent of all the professional development time was devoted to an integrated approach and involved the direct training in the UbD curriculum method Stage 2 and Stage 3 sessions, construction of the initial grade level units, and development towards and presentation of the unit draft. The final unit presentation, minus 20 minutes, was interdisciplinary in nature and accounted for 7% of the total training time. Various forms of intradisciplinary integration (cellular, connected, and nested), 9%, were used for the introductory sessions, some development of presentations, and revision of units. Two training sessions, 3%, were interdisciplinary in nature. All percentages have been rounded to the nearest half percent.

Table 11 outlines four different content domains that were integrated within the STEM professional development training. In intradisciplinary cases, one specific domain was the solo focus. At other times, there was an interdisciplinary equally shared focus between two areas or a blend of three or more content domains bound within a hierarchical order. Content was also presented in which all four STEM areas were blended in equal amounts without one given more focus than another. Within the table, the use of capitals indicates dominant content domains, lower case shows a supporting domain, and lowercase italics indicate content domain playing a minor role.

Table 11

Integration of STEM Content Domains within Professional Development Curriculum

Integration	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	O*	N†	Total
Intradisciplinary *Connected*											
General STEM	45	0	0	0	0	0	0	0	0	0	45
SCIENCE	45	0	0	0	0	0	0	60	60	0	165
TECHNOLOGY	0	0	30	0	0	0	120	0	0	0	150
Interdisciplinary *Shared*											
SCIENCE-ENGINEERING	0	0	0	0	0	120	0	0	0	0	120
SCIENCE-TECHNOLOGY	0	135	0	0	0	0	0	60	0	0	195
TECHNOLOGY-MATHEMATICS	0	0	0	0	0	70	0	0	0	0	70
Interdisciplinary *Shared*											
SCIENCE-engineering-*technology*	0	0	0	0	0	0	0	0	120	0	120
ENGINEERING-science-*mathematics*	0	0	130	0	0	0	0	0	0	0	130
ENGINEERING-technology-*science*	0	0	0	135	0	0	0	0	0	0	135
Integrated *Webbed*											
BALANCED STEM	0	0	0	0	355	0	0	0	0	0	355
Daily Totals	90	135	160	135	355	190	120	120	180	0	1485

Note: D=Day. O=October. N=November. Balanced STEM denotes the training at the airport where all four areas of STEM were present in equal amounts. General STEM indicates the umbrella introduction to STEM. Capitals indicates dominant content domain(s) lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role. Chart excludes time spent per day on professional development not directly tied to STEM content knowledge training. Total number of minutes is 1485.

Overall, slightly more than half or 52%, of the STEM content was interdisciplinary in nature. Of this shared typed, science and technology were the dominating domains within the dyad forms at 26%. Science and engineering shared 26% of the core focus within the triad forms. Intradisciplinary integration made up 24% of the STEM content, with science and technology comprising 11% each. The other quarter, 24%, was made up of webbed integration, themed around aviation with none of the four content areas more predominant than the others. All percentages have been rounded to the nearest half percent.

Table 12 ranks integrative STEM categories according to the percentage of the 1485 minutes devoted to the development of STEM content knowledge.

Table 12
STEM Content Integration Ranked by Amount of Time in Professional Development.

Rank	STEM Content	Time	Percent	Total %
1	BALANCED STEM	355	24	24
2	SCIENCE- TECHNOLOGY	195	13	37
4	SCIENCE	165	11	48
5	TECHNOLOGY	150	10	58
6	ENGINEERING- technology-*science*	135	9	67
6	ENGINEERING- science-*mathematics*	135	9	76
7	SCIENCE- ENGINEERING	120	8	84
7	SCIENCE- engineering- *technology*	120	8	92
8	TECHNOLOGY-MATHEMATICS	70	5	97
11	General STEM	45	3	100

Note: Balanced STEM denotes training where all four areas of STEM are present in equal amounts. Capitals indicates dominant content domain(s) lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role. Chart excludes time spent per day on professional development not directly tied to STEM content knowledge training. Total number of minutes is 1485.

Content that was most integrated took place during the one-day field trip to the local airport and made up 24% of the total STEM content training time. Within the context of STEM content taught over a number of professional development days, 34% was devoted exclusively to science, technology or a combination of both. However, 8% of the time, science was a primary focus with technology and engineering playing secondary roles.

Neither engineering nor mathematics were explored as stand-alone content domains. Engineering, with the focus on the design loop, was paired with all the other STEM content areas 18% of the time. It shared a duel focus with science 8% of the time. Mathematics, in a similar fashion, shared a focus with technology 8% of the time.

Overall, science was either dominant or had an equally shared focus with one other domain, 40% of the time. Technology, when analyzed in a similar fashion, made up 28 % of the time spent on developing content knowledge during the ten days. Engineering and mathematics, using the same construct, took 18% and 5% respectively.

In sum, this section established the integrative nature of the professional development from the general to the specific. Distribution of time spent on the STEM and UbD strands was studied, with the times and integration types of each session within each stand discussed. How the four domains were integrated and ranked within STEM ended the section.

Exit Cards. Eight exit cards were issued during the Project Flight professional development (Appendix F). Seven were dispensed during the two weeks of summer professional development from June 9, 2014 to June 19, 2014, with one final card being issued on October 11, 2014 during the fall training. All cards were designed to measure teacher self-perceptions of efficacy. Six out of the eight were three paired sets, given Monday through Wednesday, on a weekly basis. Efficacy in applying the NGSS standards was asked on Monday, STEM in the classrooms on Tuesday, and writing STEM lessons using UbD on Wednesday. While all 14 of the teachers filled out exit cards for the first week, 11 filled out exit cards on the subsequent Monday, 12 on the Tuesday, and 11 on the Wednesday which resulted in 76 cards being used for this study. An additional exit card, given on the Thursday of the first week, looked to uncover teachers' efficacy of differentiating within a STEM classroom while the final October exit card asked Wednesday's question coupled with an inquiry about what the teachers would like to see during the final training. All the exit cards contained both quantitative and qualitative data. The qualitative data collected from the teachers' written comments addressed three of the qualitative research subquestions.

Research Subquestion 1: Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within the classroom?

Research Subquestion 4: Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate STEM domains?

Research Subquestion 6: What are the perceived conduits and barriers to effective integration of engineering and engineering practices within an elementary classroom?

Line-by-line analyis was done on each exit card after the comments had been entered into an Excel sheet, followed by the coding of emerging themes using grounded theory. Selective coding was then applied, with similar codes being grouped together and the comment frequencys tabulated. Final themes were distilled into common catagories rooted by the connections and interplay between themes of the core groupings.

Table 13 indicates the resultant six broad categories, which contain the 185 analytical units of information found within the 76 exit card comments. Six sub-tables follow, each indicating the collaped themes found within each of the broad categories.

Table 13

Seven Major Categories of the Archived Exit Card Comments

Category	**Number of Comments**
Personal and Group Affective Comments	49

Category	Number of Comments
General Instructional Pedagogy and Student Interest	45
Understanding By Design Curriculum Unit Development	34
Professional Development Structural Elements	22
Development of STEM Content Knowledge	18
STEM Domain Specific Pedagogy	17
Total	185

Personal and group affective comments. The first ranked category involved the teachers' emotional reactions to the professional development. Out of 49 comments, 32 comments were indicative of postive teacher attitudes. Table 14 indicates the seven personally oriented comments and six group oriented comments.

Table 14
Personal and Group Affective Comments

Personal Affective Comments		Number of Comments
Positive Self-Efficacy		14
Postive Outcome Expectations		12
Reflections on Expertise		6
Negative Self-Efficacy		5
Goal Oriented		2
Confusion		2
Relief		2
	Sub-Total	43
Group Affective Comments		
Effective Collaboration		6
	Total	49

Examples of individual comments ranged from "more confusion than clearness" to "I am understanding the process better today. But, I am not yet confident." to "I just want you to know that I really like learning about STEM and how to create a STEM classroom". An example of a group oriented comment was "the collaboration of my group helps me see how so many ideas can be brought together to bring amazing learning opportunities for my students."

General Instructional Pedagogy and Student Interest. The second ranked category of comments concerned the teachers' general instructional pedagogy. The 17 comments involving differenciated instruction and eleven comments concerning the integration of STEM content. Both reflected the situatedness of teacher's praxis in meeting the needs of their students within their own schools. Table 15 indicates five areas of instructional pedagogy.

Table 15
General Instructional Pedagogy and Student Interest

Instructional Pedagogy Elements	Number of Comments
Differentiation	17
Integration With Existing Content	11
Maining Student Focus	8
Student Engagement	5
ELL	4
Total	45

"I work with ELL students every day in my classroom. The ideas today were very helpful," and "The differentiation concepts taught today will also be useful in reaching all learners," are representative of the comments in this category.

Understanding the design curriculum unit development. The third ranked category involved the process of curriculum design. Comments about specific design stages of UbD made up 21 of the 34 comments.

Table 16 indicates four UbD design componants in addition to two other curricular elements.

Table 16
Understanding by Design Curriculum Unit Development

Curriculum Aspects	Number of Comments
Understanding Alignment of Curriculum	10
Editing and Revision Process	8
Assessments and Performance Tasks	8
Stage 1 KUD	5
STEM in UbD	2
Links to CCSS and the Arkansas Science Frameworks	1
Total	34

"I feel like I am gaining a better understanding of the elements of a STEM unit. I still need help with the UbD tasks and incorporating the STEM aspect within that." is a representative comment found in this category.

Professional Development Structural Elements. The fourth ranked category addressed specific design aspects of the professional development training. Ten comments involved aviation experts while 12 concerned group process. Table 17 illuminates the four elements within this category.

Table 17
Professional Development Structural Elements

Structural Elements	Number of Comments
Need for Time to Collaborate	8
Field Trip to Airport	7
Sharing Out of What Individuals Learned	4
Value of Expert Speakers	3
Total	22

"Spending more time in groups discussing ways to pull the STEM parts has helped. I also enjoyed seeing other group's units. Getting feedback from the instructors has been very helpful." is a representative comment in this category.

STEM Pedagogical Elements. The fifth ranked category involved the specific STEM pedagogy which differs in scope from general instructional pedagogy. Table 18 outlines the four major elements in this category.

Table 18
STEM Domain Specific Pedagogy

STEM Pedagogical Elements	Number of Comments
Constructivism and Inquiry	6
STEM Instructional Strategies and Methods	5
Understanding of NGSS	5
Appreciation for Design Challanges	3
Total	19

Representative comments from the teachers were “importance of lift as a force- Bernoulli's Principle, too much I don't know, lots to learn still. ;.> [emoticon included in the original]” and “I really appreciated learning how to deepen my [personal] goal by asking more open-ended questions.”

Development of STEM content knowledge. The sixth ranked category involved the learning of STEM content. Cooperative learning, with seven comments, and STEM domain specific content comments, with 11, made up this category. Table 19 indicates the breakdown of the elements.

Table 19
Development of STEM Knowledge

Content Elements	Number of Comments
Cooperative Learning From and With Peers	7
STEM Content	6
Prior Background Knowledge	3
Learning About Misconceptions and Task Analysis	2
Total	18

An inclusive comment from a teacher involved many aspects of this table. The professional development items that supported the teacher's score were,"Activities with Bernoulli's Principle, Learned the 4 Question Strategy and how/when it applies to the design loop. Fleshed out Stage Three--Great Teamwork!".

In sum, three research subquestions were addressed within the exit cards. Subquestion 1 revolved around teachers' perceptions of the NGSS standards, Subquestion 4 concerned their perceptions of how to integrate STEM domains, and Subquestion 6 looked for barriers and conduits to integration of engineering and engineering practices in an elementary classroom.

Curriculum Units

During the course of the Project Flight training, four curriculum units were developed. Third grade teachers opted to sub-divide into two groups, those from Eastside School and Northside/Westside School developed differing units based on the same standards. Fourth and fifth grade teachers elected to remain in single grade level groups to develop a common curriculum unit to be taught across all three elementary schools. The first draft of the grade level curriculum unit was written by June 16, 2014. Modifications to the units, due to additional professional development training, occurred during the first follow up session on October 11, 2014. The final and complete versions of the curriculum units were presented on the final day of professional development on November 8, 2014.

Three of the qualitative research subquestions were addressed through the analysis of the four curriculum units, the teacher selected STEM lessons and end assessments. The questions were:

Research Subquestion 1: Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within the classroom?

Research Subquestion 2: How do engineering and engineering practices manifest within a teacher constructed elementary STEM curriculum unit?

Research Subquestion 3: When teachers are contructing STEM curriculum units during STEM professional development, what is the role of engineering in comparison to the STEM subject domains and how is engineering integrated within the unit design?

In order to examine teachers' perceptions of the NGSS , each unit's enduring understandings and essential questions were reported to contextually frame the unit, followed by an overview of the given standards and their connection to the core subject domains. Any missing standards, as indicated by the content of the lessons were noted, and the occurances of standards was tabulated by percentages of the total.

To understand the role of engineering and how it was integrated in comparison to other content domains, depending on the structure of the grade level unit, either the daily lesson plans or weekly lesson plans were designated as the curriculum units of measure. Each lesson was reviewed for the content domains being taught and the degree to which each domain made up of the total lesson. The domains were then categorized according integration form. Further clarification for each step is below.

The lessons were reviewed for purpose, objective and procedure to determine the subject areas which could differ from how the teachers designated the content within the unit. For lessons involving more than one content area, two things occurred. First, the degree to which each of the content areas made up the lesson was determined as well as establishing how each functioned in relationship to each other. There were three possible options, a content area could be the dominant STEM area, it could be used to support another content area, or function in a minor capacity within the lesson.

In the tables which follow, these relationships are shown by the use of capitals for the dominant STEM content domain(s), lower case lettering for a supporting domain, and lowercase italics for content domains in minor roles. In order to rank the content areas within a lesson in importance, points were awarded, with a point being awarded if a content domain was the only or dominant subject within a lesson. If two content areas were equally represented in lesson, each was awarded a point. No points were given for subjects in a supporting or minor role. These points were then translated into percentages to allow comparisons of content areas across lessons.

To determine the kind of integration, two steps were taken. First, categorization by basic integration form: intradisciplinary, interdisciplinary, or integrated (Huntley, 1998) and then further categorization into either dyad or triad forms if the lesson was interdisciplinary in nature. The dyad form represented lessons where two content domains were of equal importance or in situations where one dominant domain was supported by a lessor domain. The triad form had an additional content domain in minor role. The rationale for using the two forms was to further highlight the functional relationships between the content areas. The specific sub-category of integration, using one of the eight Fogarty (2009) integration types (cellular, connected, nested, sequenced, shared, webbed, threaded and integrated) was used to explain the curricular planning student outcome each integration type afforded.

To understand the specific role of engineering and engineering practices within each unit, teacher selected STEM lesson from the end of the summer session, the end performance assessment, and the remaining curriculum unit were analyzed to see if engineering was perceived to be a specific content domain or as a process of design as designated by the Committee on K-12 Engineering Education (Katehi et al., 2009a). If the indicated curricular element did not meet the criteria for engineering, that was stated and no determination made as to the type of engineering. Following that, the engineering habits of mind practices (systems thinking, creativity, optimism, collaboration, communication, and ethical considerations) was applied to each of the three curricular elements.

The curriculum units are presented below in ascending order by grade level, with Eastside and Northside/Westside being presented first. After all the four units have been discussed, using the methods outlined above, the results are collated and analyzed to discern trends across the units.

Third Grade

Eastside Unit. The UbD enduring understandings and essential questions throughout the Eastside unit focused on the physical science concepts of force and motion. The Eastside teachers placed specific emphasis on the “pushes and pulls that are responsible for changing movements” and “unbalanced forces cause changes in motion” in their unit’s enduring understandings. The same curriculum standards were used in both the third grade curriculum units and are represented in Table 20.

Table 20
Description of Standards Used in the Third Grade Curriculum Unit

Domain Area	Type	Quantity	Grade	Descriptions
Science	NGSS	2	3	Investigating the effects of balanced and unbalanced forces as well as observing and measuring the motion of an object.
Science	Arkansas K-8 Science Framework	1	2	Investigating the relationship between motion and force.
Engineering and Technology	NGSS	3	3	Solving a given problem by the development or an improvement of a new technology, the use of constraints, and conducting fair tests for improving a prototype technology.
Mathematics	CCSS/M	4	3	Mathematical practices standards related to quantitative abstract thinking and strategic tool and measurement standards related to using rulers and making bar graphs to represent data.

Standards. All five of the NGSS standards for science, engineering and technology were drawn from the NGSS 3-PS2 Motion and Stability: Forces and Interactions Disciplinarily Core Idea. These were used to integrate science content knowledge and the application of technological design thinking to the various activities (NGSS Lead States, 2013). At the time of unit construction, Arkansas had endorsed the NGSS standard but they had yet to be implemented. Consequently, the Arkansas K-8 Science Framework (Arkansas K-8 Science Framework) were the science standards still in use in the classroom. CCSS/ELA standards were stated in the unit plan although non-fiction reading and writing tasks were evident in within the daily lessons in terms of reading informational books, student presentations, and reflections. In terms of STEM weighting, mathematic standards made up 40% of total, science, engineering and technology made up a combined total of 30% as did the two combined science standards.

Roles and integration. To understand the role engineering had in relationship to other STEM subject domains and how engineering and engineering practices manifested specifically in the Eastside unit, Table 21 analyzes the Eastside curriculum unit's daily lesson plans and the teacher selected STEM lesson for the prevalence of specific domains and how they were integrated.

Table 21
Integration of STEM Content Domains within the Eastside Curriculum Unit

Integration	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	D 9	D 10	Total Days
Intradisciplinary Cellular											
SCIENCE		X	X			X					3
ELA										X	1
ENGINEERING									X		1
Interdisciplinary Shared (dyad)											
SCIENCE-TECHNOLOGY					X						1
SCIENCE-*ela*	X										1
TECHNOLOGY - *ela*								X			1
Interdisciplinary Shared (triad)											
ENGINEERING -technology-*science*							X				1
TECHNOLOGY -science-*mathematics*				X							1

Note: Capitals indicates dominant content domain(s), lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role.

A pattern was established within the unit of having one content area serve as the central focus of a lesson throughout nine of the days. Science was a dominant subject 40% of the time, engineering and technology were 20% each, and ELA had 10%. Science and technology shared dominance during 10% of the lessons while mathematics, although evident, played a minor supporting role. Most of the science investigations were done as a class, wherein individual students would either observe a science phenomenon revolving around force and motion, read non-fiction text on the topic or, in two cases, have structured hands-on investigations using loop planes or marshmallow shooters. In terms of weighting, in order from most dominant focus within the daily activities, the following content domains were ranked according to awarded points: science (5), technology (3), engineering (2), ELA (1) and mathematics (0).

Within the curriculum unit, 50% of the daily lessons were integrated intradisciplinary and the other half were interdisciplinary, either in a dyad or triad form. The intradisciplinary days were cellular in nature, focusing on science, ELA, and engineering which is in line with the traditional methods of teaching every content domain as “separate and distinct entity in order to reveal the critical attributes of each discrete field” (Fogarty, 2009, p. 23). The other half of the unit followed a shared interdisciplinary form of integration, as the concepts, processes and skills from each of the individual disciplines intentionally worked in tandem to reinforce core conceptual understandings (Fogarty, 2009).

At the end of the summer session, the Eastside third grade teachers selected the *Marshmallow Shooters* lesson as the best example of STEM for their unit. Using a formalized protocol, individual students built shooters out of Dixie cups and balloons, and measured the distance marshmallows and pom-poms traveled when shot out of the cups. A class discussion about the effect of force and distance preceded the building of the shooters with a follow up discussion after the investigation. The students completed individual activity worksheets. The teachers stated that science was addressed by the discussion of force on the object, technology by the creation of the shooter, engineering by the designing of the shooter and mathematics by the measuring, in inches, how far the two different objects flew when presenting the lesson to their peers (Appendix K).

While presented as using all four content domains, there were some difficulties within the designation of the content areas. Eastside teachers seemingly based their designations on whether they could find examples of the core areas rather how each domain functioned within the greater context of the unit. Investigating force and motion was appropriately designated as science. However, there was a misapplication of the NGSS 3-PS2-1 standard. This standard involved conducting an investigation to see the effects of a balanced and unbalanced force on an object and stipulated the use of one variable at a time. As the lesson was written, there was the potential to foster misconceptions within students by changing both the degree of force and the size of the object being launched while stating that "a little force won't move an object very far (or fast), but a big force will" in the same investigation. In this structured science investigation, the students were directed to use the basic science process skills of predicting, observing, measuring and inferring on a provided worksheet (Padilla, 1990). Making the shooter was indeed technology, but engineering was misidentified as the teachers provided pre-set directions on how to build the shooter without any generation or modification of design by the students (Massachusetts Department of Education, 2006).

Engineering and engineering habits of mind. The Eastside curriculum unit, STEM lesson plan and performance based assessment were analyzed in terms of type of design thinking used and for evidence of the engineering habits of mind (Massachusetts Department of Education, 2006). The curriculum unit, in Table 22, is reviewed without the inclusion of the other two.

Table 22
Eastside Curricular Unit Engineering and Engineering Habits of Mind

		CU	LP	EA	Total
Design Thinking					0
	Body of Knowledge				
	Process of Design	X		X	2
Engineering Habits of Mind					
	Systems Thinking	X	X	X	3
	Creativity			X	1
	Optimism	X		X	2
	Collaboration			X	1
	Communication	X	X	X	3
	Ethical Considerations	X	X	X	3

Note: CU=curriculum unit, LP= lesson plan, and EA= end assessment

Engineering was conceptualized as a process of designing under constraints throughout the whole unit with particular stress upon the building of a prototype, testing under constraints, and modification towards a best solution Committee on K-12 Engineering Education (2009). The Eastside teachers incorporated the loop plane from the STEM professional development and had the students apply their current knowledge of scientific force and motion to the building and modifying a prototype of the plane.

Within the context of the *Marshmallow Shooter* STEM lesson, the teachers misidentified the engineering element. The students were not required to create a tool or process to answer a need (Sneider & Purzer, 2014a) but instead followed a preset protocol that resulted in the construction of a technology (Karwowski, 2005) which was used to illuminate the effects of some of the properties of force on motion. According to Householder and Hailey (2012), this would not be an authentic engineering design challenge but a science inquiry activity with the purpose being able to observe and learn about the science phenomenon of force. Consequently, the *Marshmallow Shooter* lesson did not integrate all four STEM domains (Appendix K).

The Eastside third grade end performance assessment was to have the students work in small groups to design, build and test a model airplane hangar which could stand up to the wind forces of hairdryer. To do so, the students designed a plan for a hanger, using provided materials, and to justify how the materials were used in terms of the science concepts of force and motion. After building a prototype, the students tested and modified their structures. Following a final presentation, the students evaluated in writing the quality of their hanger to withstand the wind forces. This activity did meet all the criteria for being an engineering design challenge in that the students followed the engineering design loop from start to finish.

Within the unit, engineering was perceived as a process of design, specifically the application of the stages of the engineering design loop (Massachusetts Department of Education, 2006). Based on the Committee on K-12 Engineering Education (Katehi et al., 2009a) criteria for systems thinking, the students understood how separate materials, each with its own identifiable properties, could worked in interdependent ways to produce unexpected result. The communication of results and ethical considerations, in that there was no negative impact on students, were present in the unit as well. Optimism, the attitudinal belief that the students could design a solution for a problem was noted in the end assessment and in parts of the other activities within the unit, but not in the *Marshmallow Shooter* lesson. The elements of creativity and collaboration, outside the end assessment, were the least evident. Students worked independently, for seven out of the ten days, and within the tight guidelines of either confirmatory or structured inquiry activities (Bell et al., 2004; Rezba et al., 1999; Shulman, 1987).

In sum, the standards selected for the Eastside unit encompassed all the STEM domains with mathematics and science being slightly more weighted. However, within the unit itself, there were ELA components that were not indicated in the standards and mathematics that did not play a major role in the curriculum unit which differed from the prevalence within the standards. Within the unit, the ELA activities were used to support the three other content domains of science, engineering and technology while mathematics had a minor role. Five days were spent in lessons that were intradisciplinary and five interdisciplinary where either science, engineering or technology served as the dominant content areas. The engineering activities were presented as a process of design in two of the elements, rather than as a domain of knowledge, with the engineering habits of mind elements of systems thinking, communication and ethical considerations observable in all three curricular aspects and the elements of collaboration and creativity being the least evident amongst the aspects.

Northside/Westside unit. The teachers in the two schools also used the same standards as the Eastside teachers. The units differed as the Northside/Westside made an explicit the focus on science inquiry because "all learners [should have] opportunities to make observations, pose question, develop hypothesis, design and conduct investigations, and analyze data to draw conclusions" (Northside/Westside, personal communication, November 8, 2014). Like Eastside, there were no CCSS/ELA standards stated, even though students the curriculum unit stated that the students used science journals, recorded data and took notes.

Roles and integration. Table 23 describes the role engineering had to other STEM subject domains and how it was integrated in the Northside/Westside nine-week unit. Table 24, which then follows, displays how engineering and engineering practices manifested specifically in the weekly lesson plans, the teacher selected STEM lesson, and the end assessment concerning the kind of engineering design thinking and prevalence of the engineering habits of mind.

Table 23

Integration of STEM Content Domains within the Northside/Westside Curriculum Unit

Integration	**W 1**	**W 2**	**W 3**	**W 4**	**W 5**	**W 6**	**W 7**	**W 8**	**W 9**	**Week Total**
Intradisciplinary Cellular										
SCIENCE		X		X						2
ENGINEERING	X					X				2
Interdisciplinary Sequenced (dyad)										
SCIENCE-ENGINEERING			X							1
SCIENCE-TECHNOLOGY							X			1
Interdisciplinary Sequenced (triad)										
SCIENCE-technology-engineering					X					1
ENGINEERING-technology-mathematics								X	X	2

Note: W = Week. Capitals indicates dominant content domain(s), lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role.

Engineering was the dominant subject for four of the weeks and science for three. In terms of STEM weighting, engineering was favored 44% of the total and science for 33%. However, when accounting for shared dominance, science was prevalent for five of the weeks, engineering for five, and technology for one. Like Eastside, mathematics played a minor role. In terms of weighting, in order from most dominant focus within the daily activities, the content domains were ranked in the following way: science (5), engineering (5), technology (1), mathematics (0), and ELA (0).

After the first two weeks of intradisciplinary cellular lessons, geared towards introducing the engineering design loop and the basic science principles of flight, the remaining seven weeks of lessons comingled two intradisciplinary weeks with five weeks of interdisciplinary triad sequential integration. This unit tended toward simpler forms of content integration 55% of the time. Identification of integration was problematic, in a few instances, due to the wording used in the lessons themselves. “Build the tallest tower (paper or noodles or index cards, tape, string, marshmallows, etc.)-intro design loop and group work rubric” or “Introduce Bernoulli’s principle using the strip of paper experiment- make a prediction, experiment” serve as examples.

A signature pattern within the unit’s weekly design was to introduce a core element of force and motion through science investigations or via proposed engineering challenges. Teachers modified the Four Question Strategy, a science open-inquiry protocol (Cothron, Giese & Rezba, 1989) introduced during the summer professional development training, for use in the science inquiry lessons. As beginning third grade students, using the integrated process skills required by the original Four Question Strategy, would generally be beyond the developmental level of many of the students but the teachers scaffolded the inquiry by providing the materials, core variables, and some of the procedures within the strategy making it more developmentally assessable (Padilla, 1990; Settlage & Southerland, 2007).

A second modification of the Four Question Strategy was its use during the brainstorming stage of the engineering design loop to designate the constraints and criteria specification of a design. The CD balloon hovercraft, the straw loop plane, and paper helicopter from the professional development was incorporated as structured science lessons within the curriculum unit in order to examine the science concepts of balanced and unbalanced forces as well as lift and drag. Based on the unit plan itself, the teachers stated that they were using the engineering design loop via the generation of possible design solutions, testing of prototypes and making modifications, and within the end performance assessment by looking at multiple modifications in order to come up with the most optimal solution (National Assessment Governing Board, 2010).

The Northside/Westside teachers presented a paper helicopter as the best example of a STEM lesson at the end of the summer session. Within this lesson, the teachers stated that science was addressed by the forces acting on the blades of the helicopter while technology involved making the helicopter using man-made materials. Engineering was involved in creation of the helicopter and making modifications within the object through the use of the design loop. Mathematics was used in measuring the height from which the helicopters were dropped and by measuring a variety of variables like how long the helicopter could stay in the air or the number of rotations. Like the Eastside teachers, the designation of STEM domains was determined by evidence of the core content areas within the lesson rather than how each domain functioned within the greater context of the lesson.

Engineering and engineering habits of mind. Table 24 outlines the role of engineering in comparison to the other STEM subject domains and how engineering and engineering practices manifested within the Northside/Westside Unit.

Table 24
Northside/Westside Curricular Unit Engineering and Engineering Habits of Mind

Characteristic	Elements	CU	LP	EA	Total
Design Thinking					
	Body of Knowledge				0
	Process of Design			X	1
Engineering Habits of Mind					
	Systems Thinking	X	X	X	3
	Creativity				0
	Optimism			X	1
	Collaboration	X	X	X	3
	Communication	X	X	X	3
	Ethical Considerations	X	X	X	3

Note: CU=curriculum unit, LP= lesson plan and EA= end assessment.

Like Eastside, engineering within the curriculum unit was framed as a process of designing under constraint with a strong focus on three of the stages of the design loop: the building of a prototype, testing under constraints, and modification towards a best solution (Katehi et al., 2009a). However, the lines between the engineering design thinking and scientific inquiry were blurred. While both processes hold a number of elements in common, particularly in terms of problem solving, posing questions, gathering of evidence, and evaluation of results, the intent between the two is different. In science inquiry, the learner is the process of obtaining the key aspects and properties of scientific concepts. In engineering design thinking, the scientific principles are already understood by the learner, who is using that knowledge to solve an open ended problem (Householder & Hailey, 2012). Even though the students within the Northside/Westside were to use the "engineering loop (state the problem, generate ideas, select a solution, build the item, evaluate and present results)", they were actually undergoing science inquiry to learn the principles of force and motion using a modification of various technologies to do so.

The Northside/Westside helicopter lesson showed similar domain identifications as that of Eastside. In the lesson, the helicopter was constructed using a template rather than being researched and designed to solve an identified human need or want (Massachusetts Department of Education, 2006) Consequently, the lesson involved the modification of a technology in order to understand the scientific principles of force and motion through scientific inquiry using the integrated science inquiry skills which included elements of measurement (Padilla, 1990)

The performance based end assessment for the Northside/Westside unit had cooperative groups of students use the engineering design loop to make three different modifications on three different paper airplane prototypes, documenting the differences in functionality per modification based on the students' knowledge of force and motion. The end objective for the students was to ascertain which modification was most effective in terms of increasing the distance a plane would travel. The results of the trials were recorded in the students' science journals. The students presented the plane that worked best to the class and explained the kinds of forces which influenced the motion of the plane. The presentation was evaluated by the teacher using a rubric.

As the end assessment was written, students, as an engineering design team, were presented with a problem involving the planning, testing, and modification of the aircraft. If the students actually went through the brainstorming and design stage, then the end performance would qualify as a full engineering challenge. As the wording was problematic within the unit, an assumption that this occurred was inferred from the surrounding text. Here, too, the lines between science inquiry and engineering design thinking were blurred. The teachers stated that they were going to assess the students' abilities in science inquiry by using the engineering design loop which is a mismatch. Also, some of the language used within the end assessment is that of science inquiry, not engineering. "Remember to use what you've learned in prior experiments" or "The fourth aircraft will be your control" serve as examples.

Engineering was perceived as a process of design, specifically the application of the stages of the engineering design loop and inferred by the misidentification of technological design thinking as the engineering design loop. In terms of engineering habits of mind, all curricular elements exhibited systems thinking. According to the Standards for Technological Literacy, systems thinking is also a component of technological design thinking (International Technology Education Association, 2007). Consequently, the crossover elements between technological design thinking and engineering habits of mind could be used. Communication, ethical considerations, and collaboration were evident throughout. Optimism was evident only within the end assessment, as it involved students being able to modify a design, based on their own process, towards a solution. Creativity was lacking in all (Bell et al., 2004; Rezba et al., 1999; Shulman, 1987).

In sum, the standards in the Northside/Westside mirrored those of Eastside. Science and engineering were weighted more than technology and far more than mathematics. Four weeks were spent in lessons that were intradisciplinary in nature while five were integrated interdisciplinary with either science or engineering and, in one instance technology, served as the dominant content areas. During the end assessment, engineering was presented as a process of design, but not in the other two elements due to a confounding of science inquiry with engineering design. In terms of engineering habits of mind, systems thinking, communication, collaboration, and ethical consideration were all evident with optimism and creativity being the least.

Fourth Grade Unit. The focus of the fourth grade unit was to investigate weather and the impact it had on aviation. As enduring understandings, the fourth grade teachers looked at the importance weather had on daily decision making and the use of patterns to make informed predictions about the future. The curriculum standards developed by the fourth grade team are delineated in Table 25.

Table 25
Descriptions of Standards Used in the Fourth Grade Curriculum Units

Domain Area	Type	Quantity	Grade	Descriptions
Science	Arkansas K-8 Science Framework	13	4	Eight science inquiry and process skills combined with standards revolving around weather and force, direction and mass.
English/Language Arts	CCSS/ELA	5	4	Five standard involving the reading of informational text, writing explanatory text, and notetaking.
Engineering and Technology	NGSS	3	4	Solving simple design problems, generation of multiple solutions, and carrying out fair tests.
Technological Literacy Standards	ITEEA	6	3-5	Covered a number of roles and ways to perform technological innovations.
Mathematics	CCSS/M	1	4	Knowing relative sizes within a unit of measurement.

Standards. Each content domain was afforded its own unique set of standards. Arkansas K-8 Science Framework were used exclusively for science while the NGSS were reserved for engineering. Technology was represented by the Technological Literacy Standards, a 2000 precursor to the NGSS engineering and technology standards that share a number of similar elements (Bybee, 2010). English and language arts activities were represented by CCSS/ELA standards and one CCSS/M standard addressed mathematics. In terms of STEM weighting, science standards made up 46% of the overall total, technology 21%, engineering 11%, and mathematics 3%. ELA standards made up the remaining 19%.

Roles and integration In order to understand the role engineering had in relationship to, and how it was integrated with, the other STEM domains Table 26 categorizes the 18 day fourth grade curriculum unit's lesson plans.

Within the curriculum unit, engineering was the dominant content area 27.5% of the total, science for 17%, and technology for .5%. Equally shared dominance occurred 6 out of the 18 days. Here, science was coupled with either technology, ELA, or engineering for 27.5% of the total time while ELA was linked to technology for 11%. Blended STEM, in which all content domains were used in equal balance, occurred 16.5% of the time. Ranking of the content areas, from highest to lowest, were science (9), engineering (7), technology (4), ELA (3), and mathematics (1).

Table 26
Integration of STEM Content Domains within the Fourth Grade Curriculum Unit

Integration	**D 1**	**D 2**	**D 3**	**D 4**	**D 5**	**D 6**	**D 7**	**D 8**	**D 9**	**D 10**	**D 11**	**D 12**	**D 13**	**D 14**	**D 15**	**D 16**	**D 17**	**D 18**	**Total Days**
Intradisciplinary *Connected*																			
SCIENCE	X					X						X							3
ENGINEERING																	X	X	2
Interdisciplinary Sequenced (dyad)																			
ELA-TECHNOLOGY			X																1
SCIENCE-ELA		X			X														2
SCIENCE-ENGINEERING																X			1
TECHNOLOGY-*ela*				X															1
Interdisciplinary Shared (dyad)																			
SCIENCE-TECHNOLOGY										X	X								2
Interdisciplinary Shared (triad)																			
ENGINEERING-science-*mathematics*													X	X	X				3
Integrated Webbed																			
BLENDED STEM							X	X	X										3

Note: D=Day. Capitals indicates dominant content domain(s) lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role.

In terms of curricular integration, the fourth grade unit integrated in four ways: connected intradisciplinary, sequenced and shared interdisciplinary, and webbed integration. The most complex integration occurred from Day 7 to Day 15, in which the content was fully integrated around the central idea of aviation or was shared interdisciplinary in either a dyad or triad form. Over a three-day period, students were assigned roles, across various disciplines, that were designed to be undertaken while on a field trip to the local airport and during the two days of follow up. As such, this BLENDED STEM (designated by all capital due to the fact that all four content areas were equally dominant and represented equally) webbed portion of the unit was designed to use overlapping concepts common between all the STEM disciplines and ELA in order to introduce students "to the interconnectedness and interrelationships among the various disciplines" to cement the students full understanding of aviation (Fogarty, 2009 pp. 93-94). Shared integration had a smaller content scope of transferring of learning from one content area to another through common points of intersection. This focus of transfer was fundamental to the unit as interdisciplinary or integrated approaches took precedence over intradisciplinary integration 72% of the time.

The links between science inquiry, science process skills and technology were purposeful. The science concepts behind weather were explored through the lens of technology. In many of the lessons, technology functioned both as an organizational body of knowledge as well as the use of physical tools (Katehi et al., 2009a). Like engineering, technological innovations are designed to address human needs, a concept students would be exposed to by building and using weather tools like anemometers, barometers, thermometers, wind vanes and rain gauges to track the weather over a series of days and via the modification of paper airplanes to address different weather conditions although what the specific weather conditions were was unspecified within the unit (International Technology Education Association, 2007). Consequently, technology stood out much more as a core discipline rather than being secondary to science or engineering.

Engineering and engineering habits of mind. In Table 27, below, the fourth grade curriculum unit, STEM lesson plan and performance based assessment were analyzed in terms of the design thinking used and for evidence of the engineering habits of mind.

Table 27
Fourth Grade Curricular Unit Engineering and Engineering Habits of Mind

Characteristic	Element	CU	LP	EA	Total
Design Thinking					
	Body of Knowledge				0
	Process of Design			X	1
Engineering Habits of Mind					
	Systems Thinking	X	X	X	3
	Creativity				0
	Optimism			X	1
	Collaboration	X	X		2
	Communication	X	X	X	3
	Ethical Considerations	X	X	X	3

Note: CU=curriculum unit, LP= lesson plan, and EA= end assessment. As one of the two lessons used for the lesson plans did have a small group focus, collaboration was affirmed for the whole of the section.

The curriculum unit had three different phases. The lessons leading up to the field trip involved the integration of science, technology and technological design followed by three days of webbed BLENDED STEM activities revolving around the field trip to the airport. Starting on Day 13, the focus then shifted to lessons using science, science inquiry, engineering, and the engineering design loop. In the three lessons that were not taken up with the performance assessment, engineering was viewed as a process of design under constraints. While none of the lessons had the students construct new technologies or processes, the lessons did involve the modification of technologies, testing under constraints, and designing for a best solution, all of which are key steps within the engineering design loop (Katehi et al., 2009a; Massachusetts Department of Education, 2006).

At the end of the summer professional development, the fourth grade team designated the weather tool lesson and the modification of airplanes flown inside and outside as the key STEM lessons from their unit. Both of these lessons focused the integration of science and technology and technological design. As mentioned earlier, there are some design thinking features shared between engineering and technological design. In the case of these two lessons, systems thinking that was evident as students were required to see how the individual parts functioned within the greater context of the larger system. It was the relational dynamic between the designed object, the process and the end result that was of import in the students' understanding the affordances each of the tools provided (Katehi et al., 2009a; Lachapelle & Cunningham, 2014). The weather tool lessons were done collaboratively in groups, but the construction of the airplanes lesson did not stipulate how the students were grouped. Both lessons involved a presentation aspect as well as understanding how humans used the technology for their own needs.

The fourth grade performance assessment, using a process of design point of view, had groups of students use weather patterns to predict the kinds of modifications required on their paper airplane's design in order to cover the longest distance according to predicted weather conditions. The students tested the distance the plane could fly the next day, based on the different measures of their various weather tools, to judge the accuracy of their predictions and write a reflection evaluating their decision making process. Again, specific types of weather conditions were not mentioned within the lesson itself. Both of these lessons focused the integration of science and technology and technological design. As mentioned earlier, there are some design thinking features shared between engineering and technological design. In the case of these two lessons, systems thinking that was evident as students were required to see how the individual parts functioned within the greater context of the great whole of the systems. Again, it was the relational dynamic between the designed object, the process and the end result that was of import.

Regarding the remaining engineering habits of mind, creativity in terms of students' problem posing and problem solving was mostly absent as the teachers had preselected the problems, designated the types of technologies and the possible modifications, along with the procedures for gathering information (Lewis et al., 1998). Consequenly, the attitudinal element of optimism was found only within the end performance assessment. Ethical considerations were loosely linked to the unit's essential question of patterns used to make daily decisions and, thus, was used throughout the curriculum unit.

In sum, each of the STEM domains had its own specific type of standards within the unit. The ITEEA standards were specifically used for technology and the Arkansas K-8 Science Framework for science. Science standards made up nearly 50% of the total with technology and CCSS/ELA having near 20% each. Technology stood out as a core body of knowledge in keeping with science. All three major types of integration were evident throughout the unit with 72% of the weekly lessons being either interdisciplinary or fully integrated. Engineering was presented as a process of design with a focus on problem solutions, fair trials, and selection of best solutions. In terms of engineering habits of mind, systems thinking, communication, and ethical considerations being most prevalent and optimism and creativity were the least.

Fifth Grade. The UbD enduring understanding and essential questions in the fifth grade unit examined the concept of change in terms of how forces action upon objects and how individuals use other people's ideas to change and enrich their own thinking. Table 28 outlines the standards that were used in the grade's final unit.

Table 28
Description of Standards Used in the Fifth Grade Curriculum Unit

Domain Area	**Type**	**Quantity**	**Grade**	**Descriptions**
Science	NGSS	2	NA	Applying two of the NGSS Crosscutting Concepts: Stability and Change and Cause and Effect.
Science	Arkansas K-8 Science Standards	4	5	Investigating potential and kinetic energy as applied to motion along with using descriptive statistics and interpreting data using various forms of graphs, charts, and plots.
Technological Literacy Standards	ITEEA	5	3-5	Understanding the scope and characteristics of technology, attributes of design and engineering design, role of research and development within transportation technologies.
Engineering and Technology	NGSS	3	3-5	Identifying a human need or want, the use of constraints, and conducting fair tests for improving a prototype technology.
English/Language Arts	CCSS/ELA	7	5	Appling non-fiction reading, writing, and speaking skills revolving around explanatory texts, questioning, selection of details, and drawing conclusions.
Mathematics	CCSS/M	2	5	Mathematical measurement standard using fractional units to make a line graph and writing simple equations.

Standards. The fifth grade teachers also assigned specific standards to each domain area, with technology being linked to the Technological Literacy Standards and the engineering design loop being served by the NGSS. The unit used two kinds of NGSS science standards, however, in that the fifth grade was the only grade to include the NGSS Crosscutting Concepts. These concepts are central to the three pronged approach of the NGSS and were designed to provide an integrative framework for connecting the knowledge from the various scientific, engineering and technological disciplines into a coherent, scientific view of the world (National Research Council, 2012). In terms of STEM weighting within the standards, science made up 26% of the total, technology 22%, engineering 13%, and mathematics 9%. It is important to note that ELA, however, made up 30% of the total which made that domain the single most dominant.

Roles and integration. In order to understand the role engineering had in regards to the other STEM subject domains and how engineering and engineering practices were expressed within the fifth grade unit, Table 29 categorizes each of the ten days' lessons.

Table 29
Integration of STEM Content Domains within the Fifth Grade Curriculum Unit

Integration	**D 1**	**D 2**	**D 3**	**D 4**	**D 5**	**D 6**	**D 7**	**D 8**	**D 9**	**D 10**	**Total Days**
Intradisciplinary Cellular									NA		
SCIENCE	X	X	X								3
Interdisciplinary Shared (dyad)											
SCIENCE-TECHNOLOGY					X		X	X			3
SCIENCE-*ela*				X		X					2
Interdisciplinary Shared (triad)											
ELA-SCIENCE-*mathematic*s										X	1

Note: D=Day Capitals indicates dominant content domain(s) lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role. Day 9 has a NA as it was a review or catch up day depending on the class.

Over course of the ten-day unit, with Day Nine being reserved for review or catch up, science was the central focus of the whole unit. It was a dominant focus 50% of the time and shared a focus with technology for 33% of the time. The remaining 11% science was coupled with ELA. Mathematics played minor role and engineering was not evident. Consequently, the content domains were ranked in the following way: science (9), technology (3), ELA (1), mathematics (0), and engineering (0).

Within the curriculum unit, 33% of the daily lessons were intradisciplinary and the other 66% interdisciplinary either in a dyad or triad form, in terms of integration. The intradisciplinary days were cellular in nature and solely focused on science. The rest of the days were of a shared interdisciplinary integration form with science being a core discipline throughout. During the unit, the students learned core concepts of force via lessons connected to Newton's Three Laws of Motion and a series of structured science inquiry lessons which included the loop plane investigation introduced during the summer's professional development and a science station rotation of simple investigations on force and motion downloaded from Pinterest. Following that were a series of highly structured experiments from NASA on rollercoasters and two kinds of gliders based on provided glider templates.

In this case of shared intradisciplinary integration, the students were exposed to how technological design thinking could be used to support science inquiry as an overlapping organizational construct (Fogarty, 2009). Specifically, the concepts of force and motion were learned through experimentation involving slight modifications of a given technology. It is important to state that science inquiry was the central focus of the experiments, not the technology. Mathematics, as indicated in the grade's standards, was used as part of the data collection phase during experimentation and consequently did not play a major role as a separate content domain. In short, all content areas were used as the vehicles for science exploration.

At the end of the summer session, the fifth grade teachers selected the *O-Wing Loop Plane* as the best example of a STEM lesson for their unit. Students worked in small groups conducting a series of short controlled experiments, in which incremental changes on the size of the wing were measured in order to gauge differences of flight performance in an otherwise unchanged straw glider. The students filled out a standard protocol which included a fill-in-the-blank area for three trials of the plane as well as an open response for writing the results along with proposed modifications for improving the experiments. As such, this lesson did not diverge in intent and form from the other lessons in the curriculum unit.

Engineering and engineering habits of mind. In Table 30, below, the fifth grade curriculum unit, STEM lesson plan and performance based assessment were analyzed regarding the type of design thinking used and for evidence of the engineering habits of mind.

Table 30
Fifth Grade Curricular Unit Engineering and Engineering Habits of Mind

Characteristics	Elements	CU	LP	EA	Total
Design Thinking					
	Body of Knowledge				0
	Process of Design				0
Engineering Habits of Mind					
	Systems Thinking	X	X	X	3
	Creativity				0
	Optimism				0
	Collaboration	X	X	X	3
	Communication	X	X	X	3
	Ethical Considerations	X	X	X	3

Note: CU=curriculum unit, LP= lesson plan, and EA= end assessment

Within the course of the curriculum unit, after introducing the engineering design loop on Day Three linked to the loop plane experiment, engineering as a content domain in and of itself was not addressed. None of the other activities include any aspect of engineering, but instead focused upon building a prescribed prototype, conducting fair tests and generating possible solutions. Because the activities were so prescriptive, students did not identify a need, brainstorm, research or plan for a solution (Massachusetts Department of Education, 2006). As there was no problem posing and problem solving generated by the students, there was no creativity apparent within the unit.

In keeping with the fourth grade unit, however, there were elements of technological systems thinking, communication and ethical considerations found within the science investigations and experiments which mirror those of the engineering habits of mind. In terms of cooperation, students worked both in small groups and individually with a whole class debrief. The teachers selected *O-Wing Loop Plane* did have design thinking included. Like that of the third grade, this was not an engineering design challenge but, according to Householder and Hailey (2012), a science inquiry activity designed to have the student learn about force and motion.

The end performance task was to build, test and modify two different models of airplanes based on the glider and delta wing glider from the *Aeronautics: An Educator's Guide with Activities in Science, Mathematics, and Technology Education* program (National Aeronautics and Space Administration, 1999). These two lessons were followed up by class discussions "around what forces are happening on the plane and how that is affected when changes are made…and compare and contrast to previous experiments". On the third day, students presented the results of their glider modifications and linked them to Newton's Three Laws of Motion and a graph of their science data using the mean, median, mode and range for the three trials. As written in the NASA lesson, the students constructed individual gliders and conducted a series of tests. Students were grouped only at the end in order to submit a team student record sheet per glider. In terms of engineering, the end performance mirrored that of the curriculum unit as a whole, in that it was an application of technological design thinking within the context of science inquiry.

Overall, the standards used within the fifth grade unit were geared towards ELA, science and technology with engineering and mathematics being less prevalent. Science was the intentional and pervasive focus of the whole curriculum unit with technology, mathematics and ELA being used as support for the students learning related to force and motion through structured scientific inquiry. A third of the unit was intradisciplinary and other two-thirds were interdisciplinary with science the dominant domain. Engineering was not represented in the unit but instead was substituted with technological design thinking. Because there are mirrors between engineering habits of mind and technological design thinking, it was possible to identify systems design thinking, collaboration, and ethical considerations within the three curricular elements. Because the lessons were so prescriptive and engineering, as a content area was not evident, the elements of creativity and optimism was not in evidence.

Three research sub-questions were addressed in the analysis of the curriculum units, the teacher selected STEM lessons, and end assessments. Subquestion 1, involving teachers' perceptions of the NGSS was analyzed by determining the role the NGSS standards within all the standards of the units. Subquestion 3 looked to see how engineering and engineering practices were integrated within each curriculum units and between the all units. Subquestion 4 concerned the role of engineering and how it was integrated within curriculum units when compared to other subject domains.

NGSS Standards. There was a consistent use of the NGSS standards within and between all curriculum units linked to engineering. The engineering design loop stages of working with constraints, fair tests with modifications, and finding solutions were the most common properties. Aside from the third grade unit, which used the NGSS standards as the major science content standards, the other two grades used the only the current Arkansas K-8 Science Framework for science content. Both fourth and fifth grade designated the Technological Literacy Standards for technology. The fifth grade incorporated two of the NGSS Crosscutting

Concepts explicitly into their curriculum standards using Stability and Change and Cause and Effect, while the fourth grade indirectly referenced patterns and the third grade discussed change within the context of all three units' essential questions. It could not be determined if the inclusion of CCSS/ELA or CCSS/M came from looking at the NGSS standard or were derived independently. Table 31 summarizes the standards from the four units while 32 specifically looks to how the NGSS were used within the standards.

Table 31
Ranking of Content Area Standards within Units by Percentage of Unit Totals

Grade	First		Second		Third		Fourth		Fifth	Total
G3E	Mathematics	40%	Engineering	30%	Technology	30%				
G3NW	Mathematics	40%	Engineering	30%	Technology	30%				
G4	Science	46%	Technology	21%	Engineering	11%	Mathematics	3%	ELA	19%
G5	ELA	30%	Science	26%	Technology	22%	Engineering	13%	Mathematics	9%

Note: G3E= Third Grade Eastside, G3NW= Third Grade Northside/Westside, G4= Grade 4, and G5= Grade 5.

Table 32
NGSS Standards Used in Grade Level Curriculum Units

Domain Area	Type	Quantity	Grade	Descriptions
Science	NGSS	2	3	Investigating the effects of balanced and unbalanced forces as well as observing and measuring the motion of an object.
Engineering and Technology	NGSS	3	3	Solving a given problem by the development or an improvement of a new technology, the use of constraints, and conducting fair tests for improving a prototype technology.
Engineering and Technology	NGSS	3	4	Solving simple design problems, generation of multiple solutions, and carrying out fair tests.
Science	NGSS	2	NA	Applying two of the NGSS Crosscutting Concepts: Stability and Change and Cause and Effect.
Engineering and Technology	NGSS	3	3-5	Identifying a human need or want, the use of constraints, and conducting fair tests for improving a prototype technology.

Note: Both third grade curriculum units used the same standards.

Aside from the third grade, none of the units used the NGSS for as their science standards even though the NGSS has appropriate physical science standards in third and fifth grade regarding force and motion and fourth grade earth science standards on weather observations [NGSS, 2012]. The NGSS also purposely integrates engineering and technology together as a specific Discipline Core Idea (DCI) domain with the use and modification of technology folded into the engineering design thinking. Aside from third grade, none of the other two grades used the NGSS standards for this purpose although there are noted overlaps within the stated skills and practices within the ITEEA standards. Elements of conceptual integration was evident in the fifth grade unit, using two of the NGSS Crosscutting Concepts.

Balance of STEM Domains. Using each unit's curricular unit of measure, how the STEM domains were used within either the daily lesson plans or weekly lessons. In addition to the four STEM domains, ELA was also included.

Each of the five domains could be taught separately, in equal conjunction with another content area (dyad form), or be the most prevailing domain out of three wherein the second content area serves fully in support of the main while the remaining content area is evident but assumes a much lesser role (triad form). In order to quantify the weight and balance between the content domains within each unit, a system was devised in which a point was awarded to a content area that was the singular or dominant focus of a lesson, or was equally represented within the shared lesson, or was used within a webbed BLENDED STEM integrated lesson. No points were awarded if the domain area played in a supporting role. Table 33, indicates the ranking of the content domains and point values within each curriculum unit. In Figure 4, which follows, the point values are converted to percentages of the total within a given unit to allow for comparison of the relative content balances between the units.

Table 33
Ranking and Dominant Point Values of the Five Content Domains with the Curriculum Units

Grade	First		Second		Third		Fourth		Fifth	
G3E	Science	5%	Technology	3%	Engineering	2%	ELA	1%	Mathematics	0%
G3NW	Science	5%	Engineering	5%	Technology	1%	Mathematics	0%	ELA	0%
G4	Science	9%	Engineering	7%	Technology	4%	ELA	3%	Mathematics	1%
G5	Science	9%	Technology	3%	ELA	1%	Mathematics	0%	Engineering	0%

Note: G3E= Third Grade Eastside, G3NW= Third Grade Northside/Westside, G4= Grade 4, and G5= Grade 5.

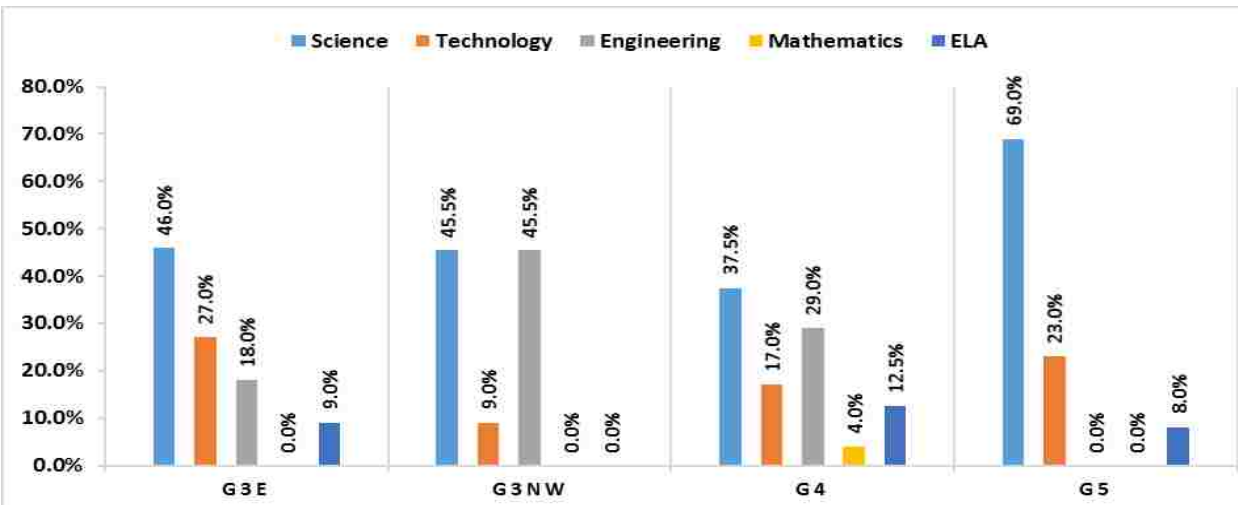


Figure 4. STEM Domain Dominance Within Grade Level Curriculum Units. G3E= Third Grade Eastside, GWN= Third Grade Northside/Westside, G4= Grade 4, and G5= Grade 5. Bars indicate percent out of 100. The absence of a content domain bar and a 0% indicates that there was no evidence of that content domain.

When the total points for each subject domain were tallied and made into percentages, science was weighted most heavily with 47%. Engineering received 23% while technology had 18.5% of total. ELA received 10% and mathematics had 1.5%. However, individual grade level curriculum units balanced STEM in unique ways. Mathematics was universally the least represented. ELA, aside from the Westside/Northside unit, however played an important role within the units, either during the researching and information gathering phase of the units or during the larger class presentations at the end of the unit. Integrated STEM, according to Lee &

Strobel (2014), requires all four of the STEM domains to be evident. Based on this criteria, the fourth grade unit was a fully integrated STEM unit. Both the third grade units exhibited three domains. The fifth grade unit was the least integrated and arguably could be described as a science unit using technology in service of science inquiry.

The high ranking and weighting of science reflects aviation's focus on the physical science of force and motion coupled to a lesser extent with the earth science concepts of weather. All the units included science investigations prior to the end performance assessment. The investigations were of two types. Confirmatory inquiry, in which either the teacher or the curriculum material selected by the teacher posed the question, procedure, provided guidance on how to interpret the results, and/or was designed to bring about an expected end outcome. The rest of the investigations were structured inquiry, wherein part of the investigation, generally the testing and end results, were open and student driven. None of the investigations were guided, in that the students developed the methodology, or open inquiry, where the students designed all aspects of the investigation including the initial question (Bell et al., 2004; Rezba et al., 1999; Shulman, 1987).

The prevalence of technology and engineering as domains were relatively close and hinged upon the role each played in relationship in the science investigations. Prior to the end performance, where the students were engaged in confirmatory or structured inquiries, the students did not create or design a new process, product or technology. The process, product or technologies were provided by the teachers, generally through a template or specific set of directions. At times, students were specifically studying the technology, how it functioned, or the effects it had on society made technology the central content domain (International Technology Education Association, 2007; Karwowski, 2005). However, if the students were modifying a technology in order to learn science concepts, then the technology was integral to the scientific inquiry itself. Engineering practices were also used in a similar way. At times, the focus was firmly upon the application of the full design loop within a design challenge, as was the case with Northside/ Westside lesson having the students building a tower, or more often the case was having specific steps of the engineering design loop like building of a prototype, testing under constraints, and using fair trials standing in for the basic or integrated science process skills within an investigation (Householder & Hailey, 2012).

The low incidence of mathematics can be attributed to its limited used within the basic and integrated science process skills via a function of the collection and analyzing of data during the process of science inquiry (Padilla, 1990). Aside from having students assume the role of mathematician during three days of BLENDED STEM during a fourth grade field trip, mathematics was not written to be a dominant content area in three of the four curriculum units.

Forms of Integration. As discussed earlier, the various STEM domains could be addressed individually, in dyad or triad forms, or in a fully integrated from where all four of the STEM content areas were evident. Huntley (1998) stipulates three kinds of integration: intradisciplinary, interdisciplinary, and integrated. Curriculum units or lessons which encompass the exploration of a single content domain are intradisciplinary in nature.

Interdisciplinary integration, is characterized by having a specific content domain as the primary focus while using another content area to aid and provide educational context but its function has not been made overt to the student. For the purposes of this study, interdisciplinary integration was subdivided into two different forms. The dyad form, were two domain areas are of equal importance in the delivery of the content or one domain is central linked to a smaller, secondary subject area. The triad form has a central content domain but two uses two different content areas—one more important than the other to help deliver the content. The final stage is where the multiple content areas are fully integrated, and work explicitly in tandem towards a common purpose (Nargund-Joshi & Liu, 2013). Table 34, below, breaks down the individual instructional units for each of the four curriculum units. Figure 5, which follows, transposes the data of Table 34 into percentages of the total unit for across unit comparison.

Table 34
Forms of Integration within Curriculum Units

	Total	IN-Cell	IN-Connected	ITD-Sequenced	ITD-Shared	ITT-Sequenced	ITT-Shared	IG-Integrated
G3E	10	5	0	0	3	0	2	0
G3NW	9	4	0	2	0	3	0	0
G4	18	0	5	5	2	0	3	3
G5	9	3	0	0	5	0	1	0

Note: G3E= Third Grade Eastside, G3NW= Third Grade Northside/Westside, G4= Grade 4, and G5= Grade 5. Integration Categories: IN=intradisciplinary, IT= interdisciplinary, D=dyad, T=triad, IG=integrated.

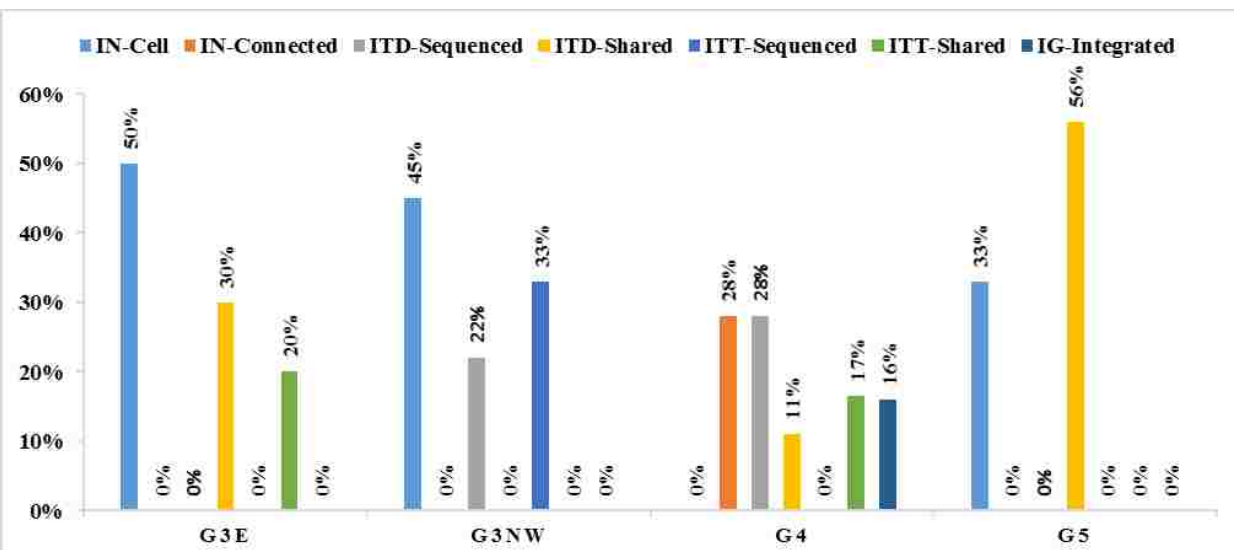


Figure 5. Forms of Integration Within Curriculum Units by Percentages. G3E= Third Grade Eastside, GWN= Third Grade Northside/Westside, G4= Grade 4, and G5= Grade 5. Integration Categories: IN=intradisciplinary, IT= interdisciplinary, D=dyad, T=triad, IG=integrated. Bars indicate percent out of 100 rounded to the nearest whole. The absence of a content domain bar and a 0% indicates that there was no evidence of that content domain.

There were some interesting trends in terms of how the various content areas were integrated across the units. Science, engineering, and to a lesser extent ELA were taught interdisciplinary. This was most evident within both third and fifth grade units, where these content areas were delivered cellularly 50%, 45%, and 33% respectively within each curriculum unit. This traditional mode of teaching, with its narrow scope, allows for teachers and students to focus on the subject and explore its defined perimeters. According to Fogarty (2009), teaching this way also allows the teachers to prepare “as experts in a particular field…and this traditional model also provides a comfort zone for all concerned because it represents the norm,” (p. 23). However, helping the learner make connections between content domains is not fostered and it is harder for students to transfer what they have learned into new situations.

Shared interdisciplinary integration, in the dyad form, was marked in both the Eastside third grade unit (30%) and fifth grade unit (56%) in the pairing of science with technology. The common purpose to use modifications in technology to illuminate key science characteristics of force and motion. In the case of interdisciplinary lessons, transfer of learning between subjects is fostered within the scope of the two domains. Eastside also included a shared triad form by having lessons using technology or engineering design loops being the central point of the lesson with two of the other subject domains being in support.

Both the Northside/Westside third grade and fourth grade units used sequenced interdisciplinary approaches using dyad and triad forms. Like the other units, science and technology were equally paired with each other or science was paired with engineering. In these cases, core steps of the design loop in terms of modifications in design, fair tests, and finding best solutions was used within the context of science inquiry. Too, ELA was paired with science or technology using this integrative form within the units and was pronounced during an end of unit presentation. Within the triad form, mathematics was used as one of the content support areas. The sequencing of lessons, wherein one content domain follows another, is a signature aspect of this kind of interdisciplinary integration and it has significant benefits. "From the students' point of view, the deliberate sequencing of related topics across the disciplines helps them make sense of their studies in both subject and content areas" (Fogarty, 2009, p. 49).

The fourth grade unit differed from the rest of the units. There was a noted degree of explicitness in the phases of the unit, with a degree of flow and signature transition points as the unit moved from weather tools to force and motion to airports to planes to the effect of weather and force and motion on planes. By using a connected intradisciplinary approach, coupled with the sequenced interdisciplinary forms, the students had the advantage of "seeing the big picture as well as engaging in a focused study on one aspect" within a sequential step-by-step progression (Fogarty, 2009 p. 32). By using a shared integrative format, the transfer of learning was facilitated at each step. The fourth grade was the only grade to have a webbed integrated approach, centered upon the theme of airports, within their unit.

Overall, interdisciplinary STEM integration was used in 50% to 56% of all the units in which two, or sometimes three, content areas were taught within the context of the same lesson. Hinde (2005) states the importance of this kind of integration in that it allows students to draw from multiple disciplines in order to develop a more powerful understanding of the central concepts.

Engineering and Engineering Practices. The nature and quality of engineering and engineering practices were analyzed within each unit, first looking to see if engineering was presented as a discrete body of knowledge or if it was presented as a process of design. The curriculum unit, the teacher selected STEM lessons, and the end of the unit performance assessment were each analyzed for evidence of the engineering habits of mind: systems thinking, creativity, optimism, collaboration, communication and ethical considerations. Tables 35, 36, and Table 37, below, present the overall scores across the units for the curriculum units, the teacher selected STEM lesson, and the performance end assessment. Following that Table 38 amalgamates and summarizes all the scores.

Table 35
Engineering and Evidence of Engineering Habits of Mind within Curriculum Units

Grade	Body	Process	Systems	Creativity	Optimism	Collaboration	Communication	Ethics
G3E	0	1	1	0	1	0	1	1
G3NW	0	0	1	0	0	1	1	1
G4	0	1	1	0	0	1	1	1
G5	0	0	1	0	0	1	1	1
Total	0	2	4	0	1	3	4	4

Within the curriculum units, minus the teacher selected STEM lesson plan and the end performance assessments, the teachers tended to misattribute elements of engineering design in two ways: (1) into aspects of science inquiry during science investigations in which the students were learning core attributes of force, motion, or weather; or (2) as the modification of an existing technology, which is technological design thinking. Consequently, only within two units was it possible to identify if engineering was viewed as a body of knowledge or as a process of design. Because engineering and technology do share elements in common, systems thinking, communication and ethical considerations were evident throughout and to a slightly lesser extent collaboration (Cross, 2001). Because the students rarely designed and brainstormed their own engineering problem, creativity and optimism were low (Lewis et al., 1998). Table 36, below, displays the full range of Project Flight teachers' attributions.

Table 36
Engineering and Evidence of Engineering Habits of Mind within Teacher STEM Lessons

Grade	Body	Process	Systems	Creativity	Optimism	Collaboration	Communication	Ethics
G3E	0	0	1	0	1	0	1	1
G3NW	0	0	1	0	0	1	1	1
G4	0	0	1	0	0	1	1	1
G5	0	0	1	0	0	1	1	1
Total	0	0	4	0	1	3	4	4

The teacher selected STEM lesson exhibited characteristics similar to that of the curriculum unit. The marshmallow shooters, the paper helicopter, weather tool/paper planes, and the O-ring glider all required the building and/or modification of various technologies within the context of either a confirmatory or structured science investigations. In order to be considered engineering, the science has to be already known and applied to an open ended problem which none of these were (Householder & Hailey, 2012). Consequently, no score was given concerning how the teachers qualified engineering. The engineering habits of mind, as they mirror technological design thinking in some elements, were scored similar to that of the curriculum unit in Table 37.

Table 37
Engineering and Evidence of Engineering Habits of Mind within End Performance Assessment

Grade	Body	Process	Systems	Creativity	Optimism	Collaboration	Communication	Ethics
G3E	0	1	1	1	1	1	1	1
G3NW	0	1	1	0	1	1	1	1
G4	0	0	1	0	1	0	1	1
G5	0	0	1	0	0	1	1	1
Total	0	2	4	1	3	3	4	4

The end performance assessments had two engineering design challenges, both in the third grade unit. Eastside's building of a model airplane hangar strong enough to resist wind forces showed that engineering was seen as a process of design rather than discrete body of knowledge. The Northside/Westside performance assessment, the students went through several modifications of paper airplanes to see differences in flight based on the students' knowledge of force and motion and then the selection of the best modification for increasing distance was also engineering through a process of design.

The fourth grade end assessment had students predict the weather and modify a paper airplane to address upcoming weather conditions involved the integration of science, technology and technological design. The fifth grade end assessment was similar, in that it required the modifications of wings on paper gliders coupled with an explanation of the kinds of forces acting on the modifications was also the integration of science, technology and technological design.

There was a slight shift in the engineering habits of mind, in the optimism aspect. Given that the third grades and the fourth grade end assessment start with a problem based on a human need or want and that a solution can be found and successfully implemented to answer this need, optimism can be attributed (Katehi et al., 2009a). Too, because the Eastside end performance was presented as an ill-structured problem, it involved more creative thinking (Lewis et al., 1998). Table 38 provides an amalgamation of all the scores.

Table 38
Total of Engineering and Evidence of Engineering Habits of Mind

Item	**Body**	**Process**	**Systems**	**Creati-vity**	**Optimism**	**Collaboration**	**Communication**	**Ethics**
Curriculum Unit	0	2	4	0	1	3	4	4
STEM Lesson	0	0	4	0	1	3	4	4
End Assessment	0	2	4	1	3	3	4	4
Total	0	4	12	1	5	9	12	12

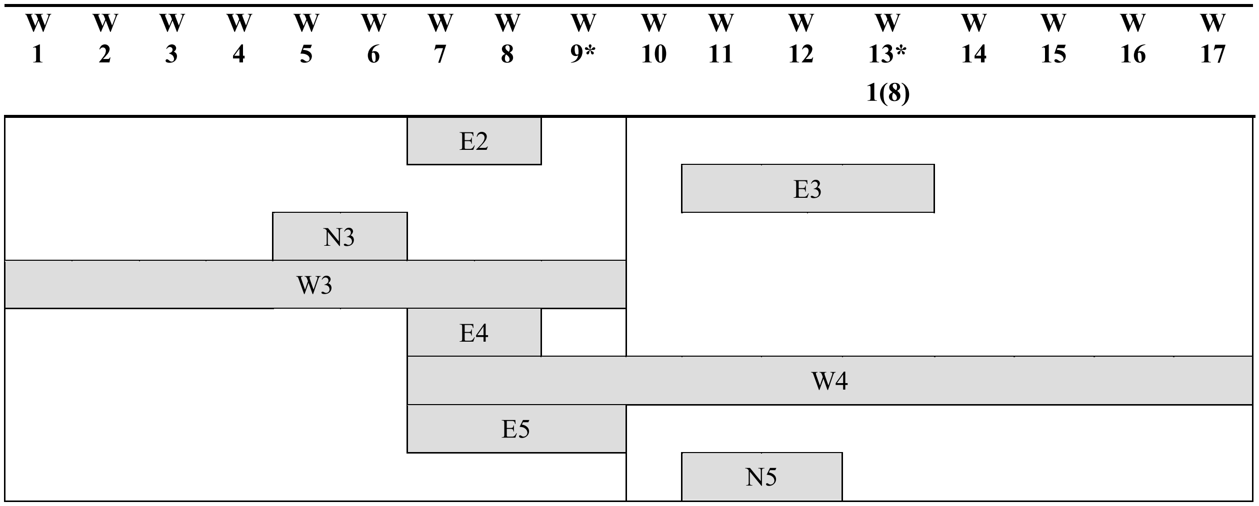
Conclusion. Within the analysis of the curriculum units, the teacher selected STEM lessons, and end assessments, three research sub-questions were addressed. In order to understand teachers' perceptions of the NGSS, Subquestion 1, each curriculum units' standards were analyzed to see how the NGSS were incorporated. The role of engineering when compared to other subject domains and how it was integrated, Subquestion 4, started with a review of the overall balance of all the subject areas within each unit and then all units were compared to each other. A similar process, but with integration as the focus, occurred thereafter. Understanding how engineering and engineering practices specifically were integrated, Subquestion 3, looked to see how these elements manifested in each unit and then were compared across units.

Current Research Data.

Current data were collected the first week of school in a set of three hour-long focus group semi-structured interviews. Data were drawn from recorded and transcribed interview responses and the researcher's field notes. Teachers filled out Think-Write-Share index cards, when prompted during the course of the interview, and highlighted their individual November grade level *Understanding by Design* curriculum unit, their own self-selected lesson plan, and filled out two sets of Think-Writes concerning their perceptions of engineering and engineering integration. The analysis of the focus group interviews and the grade level curriculum documents are discussed with the following section. Table 39 illustrates the timeline in which the teachers presented their units based on what was said in the interviews.

Table 39

Teaching Schedule of the Four Curriculum Units in the Fall of 2014.



Note: Timeline spans the 17 school weeks prior to Christmas break 2014. The vertical bar denotes the end of the first quarter of school.

* One day of Project Flight follow up training during indicated week

Focus Group Interviews.

Research Subquestion 1-Perceptions of NGSS. concerned teachers' perceptions of the NGSS standards and how those perceptions might influence their perceptions of STEM in their classrooms, began with a comparison of the NGSS to the Arkansas K-8 Science Framework. Many participants had a negative perception of the Arkansas K-8 Science Framework due to the fact that there were numerous standards to cover over an overbroad range of topics. The standards themselves were perceived to be mostly vocabulary words which required students to memorize a series of facts which stood in contrast to perceptions of the NGSS which was regarded to focus upon fostering conceptual understanding within students.

In fact, the teachers at Eastside discussed how the number of Arkansas K-8 Science Framework per grade level actually promoted student misconceptions because of the sheer number of standards. Because there was a finite amount of time that could be allocated to science within a school year, teachers found it difficult cover the required standards much less build in the necessary time for students to revisit points of confusion before having to move on to the next unit of study. Two of the third grade teachers, Ms. Miller and Ms. Johnson, addressed a current misconception students held that came to light during a third grade testing session.

> Ms. Miller: What was the benchmark question that we did? Did you guys know that plants, what is it, get energy from.
>
> Ms. Johnson: OH, from humans. Plants get human ... now I would [be] like ... "No, no. We get energy from….
>
> Ms. Miller: No, plants get energy from us.
>
> Ms. Johnson: I walked into Ms. Field 's room and just stood beside her plant and said, "I'm going to give this plant some energy." It was just that misun- ... they knew there was a transfer of energy. But they did not know which direction.
>
> I was going, "Okay, let's step back." There were days I was like, "I don't know how to address this." Yeah, plants, humans. Two different species. sometimes. Then there will be other times I just walk out just shaking my head and trying not to laugh. I'm like, "Oh, dear." I don't know how I address that. That was at the end of the day and I just looked at them I was like, "Okay, well, let's keep going." There were a lot of times it was that way (Westside, Personal Communication, June 2, 2014).

Teachers spoke about how the structure of the NGSS, which ties CCSS standards for both ELA and mathematics to each of the NGSS Disciplinary Core Ideas in each grade level, engenders integration and fosters the inclusion the teachers' own ideas into their lessons and other subject areas more effectively. This ease of use and application would serve as the foundation for building successful units, and because of the reduced number of individual standards, when compared to the Arkansas K-8 Science Framework, teachers felt that they could appropriately cover them within the scope of the classroom.

It is important to note the absence, within the interviews, of specific structural elements that make the NGSS differ from the Arkansas K-8 Science Framework. The use of the Crosscutting Concepts as integrative themes for unit, the function of the Disciplinary Core Ideas as learning progressions to build conceptual understanding across grade levels or the use of Science and Engineering Practices as a set of inquiry practices was not discussed.

In fourth and fifth grade curriculum units, pragmatic choices were made in the later stages of unit construction that resulted in the favoring of the Arkansas K-8 Science Framework over the NGSS. Teachers were strategic in selecting content that specifically matched that of the older standards as well as assuring that the Arkansas K-8 Science Framework were used as the main focal points for the science in the unit because of the requirements of benchmark testing and accountability to the old standards. Fifth grade, in particular, was strategic about doing so. Mr. Davis, from Eastside, stated that it was hard to find standards to fit the aviation lesson and “we looked at the major essential standards that we wanted to hit and focused in on those.” Ms. Brown, also from Eastside, was blunt. “Our unit was two weeks and it was a very good unit, but it was difficult for us to find two weeks to put our science standards on hold and go through it. That meant changing some activities and forgoing, unfortunately, some of them.”.

In sum, the teachers generally viewed the NGSS in a much more positive light than they did the Arkansas K-8 Science Framework although they did not demonstrate an awareness of the deeper internal structures of the NGSS that would have added some additional attributes that would be important for the application of these standards to future STEM units within the classroom. The older grades also made the deliberate decision not to incorporate the NGSS standards as fully because of loss of time and accountability for the current standards.

Research Subquestion 4-Perceptions of STEM. This subquestion looked to understand how the individual teachers’ perceptions of integrating STEM domains was influenced by the STEM professional development and the teaching of the common grade level STEM curriculum unit. There were broad categories of teachers’ thinking: the positive effects of UbD unit planning, perceptions of integrated STEM, STEM pedagogical shifts, STEM affordances in the classroom, and Perceptions of Outlier Teachers.

Positive Effects of UbD Unit Planning. Both Westside and Northside teachers indicated the benefits of preplanning a unit that kept the “big picture design” as it promoted teaching that was well thought out, effective and assured that the appropriate content knowledge was being delivered to the students. Doing so built both teacher efficacy and the desire to do more STEM in the classroom. On reflection, Ms. Wilson, a Northside teacher summed up the larger group’s attitudes towards pre-planning STEM units in the classroom when she said,

> I don't think it's as intense. You can still do STEM lessons that aren't eight hours long. You can make them simple. The kids still absolutely love it and they're still exploring. I just thought it was going to be way more intense of planning and it wasn't nearly as hard.

Being able to preplan effective, cohesive STEM units engendered a desire for more professional development in the area. Multiple teachers would like to have training that would facilitate their being able to generalize the curriculum building process to units of their own choice in order to internalize more fully the UbD process for themselves. Teachers at Eastside showed a strong desire for the self-construction of UbD STEM units, proposing professional development that would involve building mini-units based on different standards, one a quarter, in order to build up personalized resource banks of units so that “we can use that for years to come, tweaking things as we need to. It is very valuable to have that time to work together on specific things”. At Westside, Ms. Martin proposed a more traditional tack of a full year of follow-up STEM professional development which specifically focused on the blending of STEM and the NGSS standards for teachers at the elementary grades and then, at the district level, select district-wide teams to build common units to disseminate throughout the schools.

One of the ideas universal to all schools concerned the order of the professional development. Teachers recommended that gaining the required STEM specific content knowledge first and then followed by the specific pedagogical activities would be most fruitful. After relatively solid foundation was laid, the teachers recommended the construction of the UbD curriculum which involved the application of the gained STEM knowledge to their own students and specific learning environment. That way, teachers had a mental scope and sequence that they could then apply to the NGSS standards more readily. Ms. Brown, from Westside, summed up the total comments when she said the following:

> The first week we heard a lot of people talk, which was great as far as content, but we also were trying to write the unit. We were trying to pull STEM experiences and research on our own. The second week we came back and we did all of that, those experiments. We probably rewrote our unit five or six times in just that process because we were getting those experiences, we were like, “Oh, we could tie that this way.” That was our struggle.

Perception of STEM Integration. There was a range of opinions as to what constituted STEM integration. When focusing specifically upon just the four content domains within STEM, teachers at both ends of the grade level spectrum saw STEM as an intradisciplinary pursuit. For three primary teachers, STEM was synonymous with teaching science as a singular content domain where in STEM was “mainly just introducing different science concepts. We would do a STEM activity every now and then, but mostly just introducing different science and throwing in some vocabulary”. At the other end, the three Westside fourth and fifth grade teachers viewed teaching STEM as distinctly different and separate from science, in that STEM within those classrooms “would have its own procedures and set of rules and then we would go back to our normal science standards and the ways of operating”.

Four teachers saw STEM as interdisciplinary in nature. Two saw sequential integration where “connecting concepts [and] learning from one subject builds to the other that builds to the other…and you are circling back along through all those different areas of curriculum to tie them all together” while two others felt that the core disciplines bound through the shared integration of practices like inference, prediction, and estimation. For two others, all of the four STEM content domains had to be present to be considered STEM, which implies a fully integrated perception of the teaching of STEM.

However, there were four teachers who used social studies and ELA as the core subjects with STEM serving in a supporting role. Two teachers, specifically addressed this form of integration. One of the third grade teachers at Eastside spoke to how "we really had a unit where we focused on notable people. We really discussed people who have had a history with flight... we watched a film and one of our standards is to watch a film and record notes. We were able to do that, incorporating history with reading standards".

In short, the integration of STEM within the classrooms assumed a variety of different forms and levels of integration when actually being taught. Ms. Jackson, from Northside, provided an intriguing historical perspective on why the teachers might have paired the subjects that they did and why fully integrated STEM is a different way of approaching curriculum.

> What would be your acronym to integrate language arts and social studies. That tends to be what we do. It's easy to integrate language arts and social studies. It's easy to integrate science and math and adding technology and engineering to science and math is not a hard process. If you're going to add that to language and social studies…because those subject areas are easy to integrate together but if you're going to take all of it and put it together, that requires a whole different way of thinking that I think that we're not used to. As educators, we're not used to that.

STEM Pedagogical Shifts. Teachers across all three schools mentioned shifts in pedagogy towards more inquiry based practices during the teaching of the unit. Specifically, Ms. Jones targeted moving from gradual release of responsibility instructional model of *I do, We do, You do* during the STEM lessons within the unit to a more structured inquiry methodology in which "we let them explore the concept and learn it. We gave them a lot of activities to practice those theories and refine what they [the students] are thinking".

Other teachers talked the role of questioning at the start of the unit, when the teachers did not have answers for the questions students were posing, one method teachers would use would be to write questions on the board and then the students would conduct research about the questions and report back “because I couldn't be prepared for everything that was going to come out”. During the interviews, however, there were no comments that indicated if any of these shifts in pedagogy was generalized or used within the context of other units taught during the school year.

STEM Affordances. In a school with a high level of low SES students, Ms. Wilson noted that her students entered her classroom with minimal exposure to science as “they didn’t have a lot of experiences or trips to museums to have built any background knowledge” which was mirrored by the fifth grade teachers at Westside. However, many teachers believed that STEM activities were powerful agents for building community in their classrooms both at the onset of the year and thereafter.

At Eastside, all the teachers commented on how the STEM activities built “the spirit of collaboration and community building straight from the beginning. They [the students] see the value in each other”. Specifically, the teachers felt that STEM leveled the playing field in that all students could contribute in different ways during the activities and that there was a marked amount of peer accountability. In particular, students who were not strong in reading and writing could demonstrate expertise in other areas. Several teachers commented upon having students who were particularly low in the academic areas, because of their spatial awareness and creativity in terms of construction of objects, were perceived and valued by their peers as experts. From a shared responsibility perspective, because students rotated through assigned cooperative group roles, no one student could assume leadership over the whole project throughout and no student was allowed to be unengaged. This was particularly important not only during the hands-on parts of the STEM activities but also during the "other tasks, it was really helpful to have those [the assigned roles] because they all had to be working on every part of the project". Students monitored the process of each other, not because it was required, from the Eastside teachers' perceptions, but because the students were so engaged and "engrossed that they wanted to do the very best they could".

Teachers' perceptions of when to start STEM during the school year. Part of the benefits starting the school year with STEM activities was due to the community building element mentioned above. Another intriguing benefit was posited by Ms. Wilson, who saw the value of using STEM activities as a form of formative assessment.

> I would still do some of the design challenges at the beginning of the year because that was very valuable for me because I saw very quickly which students were comfortable writing or which students were comfortable reading or which students were comfortable taking a leadership role and which ones had a tendency to sit back a little bit more. That was really something that helped me at the beginning of the year to know my kids.

There was a great deal of affirmation surrounding this comment from other Eastside teachers with follow up comments about the benefits of using the design challenge again later in the year as a form of pre and post-test. Teachers in all three schools also commented on the value of starting STEM units a little bit later in the school year. Third grade teachers talked about the need for establishing core routines in the academic areas and building stamina for prolonged assignments. Teachers in the later grades explained how it helped to wait a little bit so that they knew their students better and they could make a better curricular match between the activities, the student strength and weaknesses, and knowing what to expect from the students.

Outlier Teacher Perspectives. Project Flight targeted elementary school teachers in third through fifth grade. However, there were three teachers whose teaching position differed from those of the other participants. There were two teachers who had Gifted and Talented (GT) students within the participants, Ms. Anderson and Ms. Jackson. Ms. White, due to a grade level shift within her school, moved out of a third grade position to a second grade position during the 2014-2015 school year.

Ms. Anderson, from Westside, taught a contained split class of third and fourth grade students while Ms. Jackson had a pull-out GT program that differed in frequency, time of day, and duration per grade level. Because Ms. Anderson had a consistent schedule, she was able to teach the unit with the other 3rd grade teachers at Westside. While part of the fifth grade team on Project Flight, Ms. Jackson attempted to teach that unit with her third grade GT students. “I get them two and a half hours a week...but…in three different segments. That was very difficult for them to come and go and come and go and try to maintain some fluency with it”. Instead, she developed her own lessons on buoyancy and taught it to her second grade students who she had on a more consistent basis.

Working in cooperative groups was a challenge in the GT classrooms. Ms. Anderson stated that the problem “was that they were all leaders. Even when you grouped them together, they all wanted the leadership role”. In her class, this was solved by having the students themselves delegate who was going to be the leader of the group per activity. In Ms. Jackson strategy was to have the students develop the core science inquiry questions and research in pairs but then go through the design loop individually.

The constraints on unit planning were also different for Ms. Jackson due to the differing learning needs of the students and district expectations for curriculum. “We already teach more science than what they get in the regular classroom because we're interest-based. We already do more experiments, more scientific thinking and now of course, more design and creative-type thinking.” and “We don't follow the Common Core curriculum. We're supposed to be different than that, where our units are supposed to be different than those units. They're supposed to go deeper, farther, that kind of thing".

Ms. White, who taught the third grade unit to a class of second grade students at Westside, had a different series of adaptions she had to make. Very few of the standards, both Arkansas K-8 Science Framework and NGSS, fit her new grade level standards and it was a real "stretch to make it [the aviation unit] fit". Consequently, she modified the unit as she went along to fit the developmental needs of her students as it "was the first time they're doing any kind of experiment really". None of the other second grade teachers at Westside had attended the Project Flight training nor did they opt to teach the whole third grade unit along with Ms. White although she thought that perhaps they did some of the activities but she wasn't sure to what extent. However, the whole second grade team did take a field trip to the airport. As such, outside of the field trip, Ms. White, like Ms. Jackson taught their versions of a STEM unit in relative isolation.

In sum, the five broad categories of the positive effects of UbD unit planning, perceptions of integrated STEM, STEM pedagogical shifts, STEM affordances in the classroom, and perceptions of outlier teachers discussed teachers' viewpoints on STEM professional development, the teaching of the STEM units, and how to integrate STEM within the classroom.

Research Subquestion 5-Perceptions of Integrated Engineering. This subquestion looked to understand how the individual teachers' perceptions of integrating engineering and engineering practices was influenced by the STEM professional development and the teaching of the common grade level STEM curriculum unit. There were two broad categories which concerned perceptions of the nature of engineering as well as the teachers' perceptions of the students' engineering habits of mind.

Nature of engineering. Engineering was perceived one of three ways, the first being that it was regarded as a linear sequence of steps which mostly entailed the building of items under constraints with the intent to improve or modify an existing object. Secondly, engineering was viewed as a heuristic, spoken of as "the design challenge" in much the same way teachers would use "the scientific method". In both these two cases, engineering was not viewed as an integrated, iterative system in which each part informed and served as a foil for the others nor was it treated as a distinct body of knowledge or way of seeing the world. The third perception was that engineering was believed to be the hands-on, practical application of science.

The similarities and difference between the engineering design loop and science inquiry methodology was understood to varying degrees by some of the teachers. One teacher talked about she how liked the design loop better because it was more kid-friendly but felt that they could be interchangeable. Another stated that "science lends itself to creation or design and tweaking" while another confounded the two fairly significantly as she described how her students scientific process wasn't good at the start of the year because they were not methodical when they were choosing materials for their activities but improved later because they would give more thought to selecting materials that worked best.

Students' engineering habits of mind. The engineering habits of mind involve (1) systems thinking, (2) creativity, (3) optimism, (4) collaboration, (5) communication, and (6) attention to ethical considerations (National Academy of Engineering & National Reseach Council, 2009). In discussing their students' attitudes specifically towards engineering, the teachers paid particular attention the degree of engagement and motivation the students had in conjunction to the specific habits of creativity, optimism, and communication.

Engagement and motivation. To a teacher, every participant stated how much their students were excited by and looked forward to STEM, and in particular, the engineering found within the STEM unit. Many teachers mentioned the role of active hands-on learning involved in the construction and design aspects of the units as highly motivating for the children because "as soon as you start a STEM lesson, they get excited. They know they're going to have a hands on activity". However, this eagerness could also be a bit daunting for teachers who did not feel as confident about their own STEM content knowledge and pedagogy. Ms. Wilson's, a third grade teacher from Northside, comment was poignant.

> They loved it. It was a lot of fun. The kids always begged for science after that [the Project Flight unit] because it was our first science stuff. Then, they expected every science from then on to be just as fabulous. That put a lot of pressure on me. I didn't have time to design all these other things and that was what their idea of science was since that's how we started. They begged a lot and then didn't get as great things as they wanted.

Creativity, problem posing and problem solving. As part of the conversation during the Westside interview, the three older grade teachers (Mr. Davis, Ms. Brown and Ms. Martin), discussed their student's difficulties coming up with a variety of design options when going through the design loop. All three teachers concurred that their students were "afraid to think out of the box", would ask "those questions where you're like, 'Why are you asking that? Think. You know the answer.'" or they would retry the same modifications even through the modification didn't work in the first place. The teachers stated that sometimes they would lead the students through the design process and sometimes the students would rely on some of the abler students to get them through. These comments, although particular to the engineering design loop rather than STEM, stand in contrast the more positive views held by the teachers at Westside. Ms. Brown stated that "when it comes to the scientific process, their lack of content knowledge or experience hinders their ability to ask those guiding questions that might lead them to a different strategy".

Communication. A consistent theme across all of the interviews was the reticence of students to engage in some of the reading and writing aspects embedded within the engineering activities. There were two factors mentioned by the teachers which made a difference aside from if the students were ESOL or not, those being the grade level of the students and the degree of scaffolding and support that the students were afforded either by the teacher or by peers.

Third grade teachers spoke to the transitional expectations of the grade, wherein the students were shifting from learning how to read and write to learning how to apply what they have learned through reading and writing in other situations and how that was a struggle for the students. Fifth grade teachers in both Westside and Eastside commented about how students were more comfortable recording their thoughts, connections and reflections about what they were doing and that "it's interesting too, though, two grades later that the development is different, definitely."

Because of their population, there were many struggling readers in their classrooms. Teachers would group the students so that there was a mix of abilities, with at least one relatively stronger reader per group, or engage in cooperative learning strategies such as partner reading or having differentiated cooperative groups roles. Some teachers who had access to grade level Chromebooks in the schools did use that technology to help students with researching or the construction of glossaries. As Ms. Taylor, a fourth grade teacher at Eastside, said about her students using the Chromebooks, "They were being the teachers, my kids were. That's what I saw. I saw them come alive with that. They were having fun creating and looking up information and helping each other".

However, if students could use the reading and writing with an eye towards applying it within the context of engineering design, it seemed to make a difference for a number of students. Ms. Miller, summed up a common thread held by teachers from all of the schools:

> Anything that had to do with the designing, anything that had to do with the hands-on where they could go and apply the stuff that they were learning, that was what made this so valuable in my opinion. Because they were able to create something and they didn't just hear it from me or didn't just read it in a textbook, it became very real for them. They were a lot more excited about it.

In sum, engineering was perceived in three ways: as a linear sequence of steps, as a heuristic, and as the practical hand-on application of science. Engagement and motivation were noted by the teachers and linked to the engineering habits of mind elements of creativity, optimism, and communication. The teachers from the three schools had differing perceptions concerning how their students approached engineering design and differed in how the addressed engineering in the classroom with their students.

Research Subquestion 6-Conduits and Barriers to Effective Integration. This subquestion looked to explore the barriers and conduits for the effective integration of engineering and engineering practices within elementary classrooms. There were four broad themes which occurred within the interviews: what is tested is what is taught, school policies, time constraints and curriculum choices, and school culture and social dynamics.

What is tested is what is taught. The Arkansas Benchmark Exam (ABE), administered in the early spring of the school year, was used to chart yearly annual progress in public schools across the state. Literacy and mathematics ABEs were administered in third through the eighth grade. Science ABEs were given in fifth and seventh. The fifth grade ABE, consequently, was used to evaluate the end of program science knowledge of students as they exited elementary school (Arkansas Department of Higher Education, 2014).

In the Project Flight school district, 43% of the students were English Language Learners. Hispanic and Marshallese students made up a large block of the student population within all three of the teachers' schools: Northside (91%), Westside (78%), and Eastside (67%). The schools also had a high percentage of students on free and reduced lunch: Northside (97%), Westside (87%), and Eastside (72%) (National Center for Educational Statistics, 2013). Consequently, the measures taken to help students score above a basic ranking on the state mandated tests had profound effects on the teaching of science and the teachers of Project Flight through school policies, time constraints on curriculum choices, and the differing social dynamics between the three grade levels at Eastside and Westside.

School policies. At Northside, additional constraints were placed on the time teachers could do STEM in the classroom. According to Ms. Wilson, a third grade teacher at Northside, their school was made up of near 90% of students who were ESL. Consequently, they lost nearly an hour and forty minutes of instructional time to grade level interventions and a pilot of the ELD, or Systematic English Language Development, program that took dedicated hour of instructional time out of the day with the intent of increasing ESOL student's levels of English proficiency (Achieve., 2016). Out of 21 children, Ms. Wilson had two children were proficient in reading and three for math and "as much as we want to teach big units on science, they've got to catch up on reading and math and stuff. We did try to pull in science into the reading because we just have to do it [the reading]". Additionally, at a district level, there were assessments that had to be turned in that measured student proficiencies at each grade level at each school, which also added another layer of data collection and constraints on the teachers in terms of curriculum delivery, in that, to get the students ready "to do an assessment and be successful at it, I do have to do some more scaffolding or build in a few other lessons".

Time constraints and curriculum choices. All the third grade teachers and the Westside fourth grade retained the units' planned sequence and content of unit lessons. However, the fourth grade teachers at Eastside reduced the amount of time spent building the weather tools so that they were able to move on to the design elements at the end of the unit as the deadline for finishing the project December of 2014. The fifth grade teachers at Eastside indicated that they had to weigh the value of doing activities that were not directly tested by the current Arkansas K-8 Science Framework. Ms. William's stated that they made a number of modifications because once "reality set in" they had to prioritize what was the most important knowledge to teach. Ms. Brown best summed up the time pressures, realities of testing, and changes to the fifth grade unit between the end of the summer unit and the final unit in November, this way:

> I'm being tested and I'm panicking because, all right, we're taking two weeks. This is not even going to be ... it's like I really pushed a lot of focus into the kinetic and potential energy because that is tested in fight grade in benchmark. I really made sure they got the kinetic, potential energy in. I refocused a little bit on that stuff because panic was setting in on me.

School culture and social dynamics. The fifth grade teachers in Eastside voiced several concerns about how science was being taught in the earlier grades and how that might continue under NGSS. STEM in the earlier grades was, in the view of the fifth grade teachers, not rooted in science or science practices but instead was a series of fun activities that did not build science understandings within the students. Ms. Brown spoke to the greater levels of student misconceptions and "false science information" about science that she attributed to the increased STEM lessons, in the form of STEM Fridays, being taught in the earlier grades over the last couple of years which she attributed to the teachers not "wrapping back around and finishing the STEM lesson" whereas in fifth grade when lesson was taught the students could identify the core science standards embedded within the lesson. Ms. Martin, during the course of the Eastside interview, expanded on this concern by stating the following:

> They go on and they go, "Yay, this is fun", and they learned no science. Then, when they get to fifth grade they have science that we're attaching to these STEM activities, what happens is they go, "Well, when are we going to blow something up? When are we going to do something?" They look at science as all of these fun activities. It can be incorporated in that, but when they have to put the knowledge of science as a grade, as a more definite understanding, then you have a real big hole built over time…if we took Next Gen and developed it with STEM, one of the things I see on both, being an end of the building science teacher, is that K-4 will pick and choose what they feel good about teaching. We don't have that luxury. We have to teach it all.

Ms. White, a third grade teacher, addressed these concerns after a moment of silence, by stating that if Next Generation were to become the state standards all teachers would be required to use them and that there would be more science at the earlier grades.

> "I get what you're saying. I have done some that are just like, 'Let's try to build this thing out of spaghetti and marshmallows'. We never tied it back. Whereas the Picture Perfect Lesson that we taught [a NSTA series which links literature to appropriate inquiry based science] it was more like, 'Let's learn about this and then we'll do this activity.' Then, we go back to why it worked or whatever.

Throughout the Eastside interview, in terms of science, the division between the fifth grade and the rest of the participants was evident with the fifth grade teachers holding to their statements that science expertise happens only at that grade level and that students were coming to them unprepared. The third and fourth grade teachers, did not challenge the assumptions of science expertise of the fifth grade teachers, but did address the assertion that they lacked science expertise themselves with statements like "We let them explore the concept and learn it. We give them a lot of activities to practice those theories and to refine what they're thinking" or "Going back to what they said before, we weren't just randomly doing a STEM activity. We were doing a STEM activity because it was helping them understand the science concepts.".

In the Westside interview, like the Eastside interview, the topic of fifth grade teachers being responsible for the science ABE and for teaching science did come up. However, it was not one of the major themes of the interview and the perceptions of the grade levels about each other differed. Ms. Williams, when discussing the range of Arkansas K-8 Science Framework early grade teachers had to contend with, argued that the standards hit such diverse areas that the teachers were not even sure how to approach how to do the science and, consequently, it wasn't taught as often.

> Ms. Williams [a fifth grade teacher]: Because traditionally, kids had to wait until 5th grade to get down and dirty into science [a number of affirming head nods and agreement from the other grade teachers]. There was so much, it was like a little blink here and a little blink there…sometimes I felt like I'd failed them [the students] to a degree. I didn't have the time to help them because they were so engrossed in science, loved it so much, I felt like I didn't have enough time to give them the knowledge to get where they needed to be.
>
> Ms. Taylor [a fourth grade teacher]: You were trying to do six years.
>
> Ms. Williams: I sure was.

This interchange exemplifies a difference in approach to the realities of benchmark testing between the two schools in terms of science, which in the case of Westside, was not a divisive factor. The fifth grade teachers did not challenge the expertise of the earlier grades but instead approached the lack of science teaching as a reflection of their reality of where time allocations for instruction had to go. On the part of the fourth and fifth grade teachers, there was a recognition of, and empathy for, the pressure the science ABE placed on the fifth grade teachers.

As discussed earlier in the NGSS section of the interview, student misconceptions were perceived to be a function of the pressure to cover a large group of standards across many topics rather than a lack of skill on the part of the earlier grades. Comments by the fourth and third grade teachers indicated expertise equal to that of the fifth grade teachers. For example, the third grade team decided to extend their unit over the time allotted originally because, as Ms. Miller showed the mindfulness of approach of the grade level team, "not only were we trying to build up science knowledge…we wanted to make sure we were adequately covering the material, the actual science and engineering as well as developing all those team building, teamwork kinds of things."

Think-Write-Shares

Written qualitative data from the 14 teachers was collected during the June focus group interviews. One of the written data sources was the individual Think-Write-Shares (TWS). The TWS were designed to allow for private responses to three qualitative research questions: Research Subquestion 1, "Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within their classrooms?"; Research Subquestion 4, "Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about how to integrate STEM domains?"; and Research Subquestion 5: "Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about individual teachers' perceptions about how to integrate engineering and engineering practices?" The TWS prompts were given orally throughout the course of the interviews and then the participants were given a few minutes to jot down their responses on index cards. Aside from the prompt, no other instruction as to the kind and organization of the response was given. The index cards were collected at the end of the interview.

There were three main phases in the qualitative analysis of each of the TWSs. Individual teacher TWS were entered into an Excel spreadsheet, from the index cards, in order to do line-by-line content analysis. As themes emerged, they were coded and then subjected to comparitive selective coding to see the relationships between the different themes. Similar themes were grouped together and the resulting frequencies charted. Table 40 indicates the six TWS which encompassed the 142 analytical units of information found within the individual teacher comments. Six sub-tables follow, each indicating the collaped themes found within each of the broad categories.

Table 40
Think-Write-Share Research Question Responses

Research Subquestion and TWS	Frequency
RSQ 1: NGSS Characteristics.	29
RSQ 4: Change in Approach.	39
RSQ 4: Professional Best Fit	22
RSQ 4: Definition of Integration	14
RSQ 4: Integrative Approach to Unit Design	15
RSQ 5: Engineering Integrative Approach	23
Total	142

Research subquestion 1-The NGSS. The first Think-Write-Share question provided insights into teachers' perceptions of NGSS science standards. Teachers provided a written response to the second interview question, "The Next Generation Science Standards are now being considered in the state legislature. How do you think the NGSS standards compare to the current Arkansas Science Frameworks?" the results of which are tabulated in Table 41 below. Twenty-five of comments indicated a more positive stance towards the NGSS while four indicated a negative perception or unfamiliarity with the qualities of the NGSS.

Table 41
RQ 1: NGSS Characteristics

Characteristics	Frequency
Stress on concept development	8
Deeper covering of content	6
Increased integration across disciplines	5
More teacher freedom to plan	3
Not being able to cover required content	3
Hard to understand/implement	2
Unfamiliarity with the NGSS	2
Total	29

Examples of positive comments were “I think they [NGSS] are better at pushing the students into deeper thought. They focus on students discovering concepts + not just memorizing data” and “[The NGSS are] crossing cutting/broad (as far as subjects/disciplines covered) and multi-dimensional (start broad-slowly work towards more complex.) An example of negative perception was “Maybe too broad/not as specific as needed. Teachers will need more PD to feel confident.” while two participants indicated an unfamiliarity with the NGSS with statements like “not real familiar w/NextGen.Standards. Think they include more STEM characteristics?”

Research Subquestion 4- STEM. The second through fifth TWS provided data for Research Subquestion 4: Does teaching the common STEM curriculum unit and STEM professional development change individual teacher’s perceptions about how to integrate STEM domains? The second TWS focused on the curriculum aspect by asking, “If you had to use the NGSS standards next year, would that change how you would approach STEM your classroom?” while the third TWs targeted the professional development by inquiring, “Part of professional development is looking for an effective fit between teacher needs and provided training. If we could go back in time, knowing what you know now, what could be done to provide a best fit for you personally?” The fourth TWS focused on integration by asking, “What is your working definition of what it means to integrate curriculum?” and the fifth TWS asked, “What was your group’s approach to integration when you all were designing your common curriculum unit?”. Results for the four TWSs are tabulated in Table 42, Table 43, Table 44, and Table 45 below.

Changes in approach. The results for the second TWS regarding teachers’ perception of changes they would make in their approach to STEM if the NGSS were to become the adopted science standards. The results are charted in Table 42.

Table 42
RQ 4: Projected Change in Approach to STEM

Characteristics	**Frequency**
STEM fit to standards	10
Didn't state directly	6
Change	5
If mandated would teach STEM more	5
Serves as a foundation for content	5
No change	3
Need for more professional development	3
More integration	2
Total	39

Teachers were mixed in terms of directly stating if their approach to STEM would change, with one teacher saying "I don't think Next Gen will change my approach [underlined in the original], to another who said, "I would assume there are more STEM activities so I would approach STEM w/more frequency". Six teachers did not address their own actions but wrote about the characteristics of STEM. Ten teachers directly addressed shifts because of STEM being part of the NGSS standards, "I think I would use more STEM lessons due to matching better with the new standards." Five teachers denoted because it was mandated, more time would be spent on STEM in the classroom.

Changes in professional development. For the third TWS, which delved into teachers' perception of the changes in professional development training that would help each of them individually make a better educative fit are listed in Table 43.

Table 43
RQ 4: Professional Development Fit to Teach Integrated STEM

Characteristics	**Frequency**
More resources to extend learning	8
Integrated lessons used in training.	7
Other units tied to different standards	4
Support to construct new units	2
Satisfied with training format	1
Total	22

Regarding better fit for professional development, eight teachers wanted access to more resources—from print, to videos of teachers teaching, to other UbD units in order to extend their own learning or to construct new units. Seven teachers stated that they would have liked to have the professional development curriculum be integrated so that they could see a model of integration in action. "Curriculum that combines subject areas to make connections throughout the different areas", was indicative of comments of this type. Four teachers wanted professional development that covered more standards and topics. An encompassing quote was, "[I would like] resources for creating units-or at least lessons-around other standards so that that my STEM momentum might have continued".

Integration. The results for the fourth TWS, which asked for the teachers working definition of integration, are listed in Table 44 below.

Table 44
RQ 4: Definition of Integration by Type

Integration Types	**Frequency**
Interdisciplinary- sequenced	6
Stated process not definition	5
Integrated-cross discipline	2
Interdisciplinary- shared	1
Total	14

Seven out of 14 of the teachers' definitions of integration meant that two domain areas should be to be taught in tandem (interdisciplinary) and in support of each other. "Integration of curriculum means that I am addressing standards under a variety of domains simultaneously and continuously" serves as an example of responses of this nature. Two of the definitions were integrative, in that the domains were blended into each other, in that the integration meant "seeing a seamless flow between curriculum-students don't know if they are working on math, science, writing or reading". Five of the teachers did not respond with a definition of integration but instead stated either the process or the elements they used for integrating the content.

Integration process. The results for the fifth TWS, Table 45, asked teachers to illuminate the process their group took towards integration while constructing their curricular unit.

Table 45
RQ 4: Integrative Approach towards Unit Design

Integration Types	**Frequency**
Started with standards	5
Started with NGSS and CCSS	4
Recommendations for future	3
Sequencing	2
Started with science standards and ELA	1
Total	15

Nine out of the 14 respondents directly stated that they started with the standards as the basis for integration which were then coupled with the English/Language Arts and/or Mathematics components of the CCSS. Three respondents chose not to write anything on their card while three respondents offered comment upon how the professional development should have been structured ranging from a greater emphasis on reading and understanding of the NGSS standards, to focusing less on aviation, to a broader topic that more standards would apply. There were contradictory statements concerning the sequencing of the professional development, from one teacher who would like to have the following items taught in sequential order: standards, STEM and then unit development to another teacher who stated, “I absolutely loved the layout of the 2 weeks”.

Research Subquestion 5- Integration of Engineering. The sixth TWS provided data for Research Subquestion 5, “Does teaching the common STEM curriculum unit and STEM professional development change individual teachers’ perceptions about how to integrate engineering and engineering practices?” The sixth WTS asked, “Now that you have taught the unit, let’s imagine that the Next Generation Science Standards have become the Arkansas standards. You have come back to redesign the Project Flight curriculum unit to reflect what you now know about integrating engineering and engineering practices. What would be your approach towards integration this time around? What kind of specific professional development would help with doing so?” The results for this WTS are tabulated in Table 46.

The teachers responded to the integration element of the question in multiple, and sometimes, contradictory ways. Three teachers felt that engineering was integrated well enough in the current design, “I feel that engineering was already a focus as we designed this unit” while three teachers wanted to make engineering and engineering practices more prevalent, “Heavy applicable practice on the design loop”. Better alignment with the NGSS and ELA standards was the focus of three teachers while three others wanted to modify their units to reflect a constructivist inquiry stance, in one case, by “more student discovery, less teacher front loading”.

Table 46
RSQ 5: Engineering and Engineering Practice Integrative Approach

Characteristics		Frequency
Engineering Integration Redesign		
More focus on engineering		3
Engineering already a focus		2
Better fit with the NGSS standards		2
More learning by doing		2
More reading and writing		1
Develop better facilitative questions		1
No change in approach		1
	Subtotal	12
Engineering Professional Development		
Challenges/design loop modeling		3
Use with other NGSS standards		3
Break down the NGSS more fully		2
Development of questions		1
Getting grants for engineering		1
	Subtotal	9
Total		22

Regarding professional development to support the proposed engineering retrofit of the current STEM units, five teachers would like training in the NGSS standards themselves and how to incorporate engineering using other STEM topics, “I need PD to help me identify opportunities to incorporate engineering using other science standards - PLEASE”. Four teachers would like more direct modeling and resources on core aspects of the engineering practices, for example, “PD would be great to show more models of the design loop in practice”. One teacher wanted more professional development on the development of questions within a UbD unit while another wanted training in how to write grants.

Conclusion. The six TWS were used to provide teachers with the opportunity to reflect and provide individual, and private, responses to three of the qualitative sub-research questions:

Research Subquestion 1, "Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within their classrooms?"; Research Subquestion 4, "Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about how to integrate STEM domains?"; and Research Subquestion 5: "Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about individual teachers' perceptions about how to integrate engineering and engineering practices?"

Concerning Research Subquestion 1, twelve out of the fourteen teachers were able to identify core aspects of the NGSS that made it different from the current Arkansas K-8 Science Frameworks in the TWS comments. Overall, the perceptions of the teachers towards the NGSS were positive with ten teachers commenting on the integrative, conceptually based nature of the newer standards and the ease by which they could be implemented within the classroom. Two teachers, Ms. Anderson and Ms. Jones, both third grade teachers, indicated that they were not very familiar with the NGSS, even though both had the training and taught the unit. Ms. Martin, a fifth grade teacher, had negative perceptions of the NGSS regarding *other* teacher's ability to teach the standards. Ms. Moore, a second grade teacher, also stated among other positive comments, that the NGSS were "worded differently, not as easy to understand".

There were noted differences in how the terms *broad*, *narrow* and *specific* were used when the teachers compared the two sets of standards. In some cases, broad was used to indicate the scope of the NGSS, in that the standards could be applied and used across various disciplines. Broad was also used to indicate a perceived focus on a few open-ended conceptual understandings rather than the more numerous but specific content standards of the current Arkansas science standards. Broad, however, was also used as a synonym for vague in the case of Ms. Martin, who felt that K-4 teachers would "pick and choose" which standards to apply than trying to make sure all standards were covered.

The terms narrow and specific also indicated differences in defining the NGSS. Narrow, according to Ms. Miller, in terms of the NGSS reducing the "focus (in a good way), the old standards hit so many topics" and specific was used to describe the clarity of what was being required in the NGSS but the term was used in the sense that the NGSS lacked specificity, according to Ms. Martin, regarding the delineation of science core content.

Regarding Research Subquestion 4, standards were a driver for application of STEM in the classroom, in the second TWS, reflecting the teachers' reality of benchmark testing and accountability. Ms. Williams exemplified the focus on match when she stated, "I think using STEM can be applied to all standards. Next Gen may lend itself more than current benchmark, but both can use STEM." The other comments in the second TWS lends evidence to the claim that what is mandated as the standard, regardless of the characteristics of the standards themselves, is supported by professional development and allotted time within in the classroom.

The NGSS would serve as a better foundation for STEM curriculum and teaching, as indicated in the second and third TWS. The teachers wanted to be able to see integration modeled in the curriculum of the training as well as having the resources to start to build different units connected to other standards. This need indicates a jump in the teachers' conceptualization of UbD curriculum design and understanding of STEM integration itself rather than on the acquisition of the basic knowledge of UBD steps and understanding STEM content.

It is worth noting that nine out of 14 teachers, in the fourth TWS, had definitions of integration that were not science-centric in the balance of STEM domains with other subjects. The fact that five teachers did not define integration, but choose to focus upon the decision making process their group followed to integrate the curricular unit. Ms. Anderson stated that their group “discussed what the end result would be and decided how to get there” while Mr. Davis said, “We looked at our standards. We look at the major concepts that were essential and planned accordingly”. Of these teachers, only one of them mentioned a content area, reading.

Given the focus upon Understanding by Design in training, not one teacher referenced using any of the elements of UbD as a core aspect when discussing their grade level’s approach to integration in the fifth TWS, but instead referenced the standards as the foundations used for curriculum development. Four teachers referenced the Common Core, in conjunction with either the NGSS or science standards, indicating the consideration of an interdisciplinary approach.

Regarding Research Subquestion 5, understanding and applying engineering within the context of the NGSS standards was again a predominant theme throughout the sixth TWS. When combining the two subcategories, integration and professional development, eight teachers wanted a better understanding of the NGSS standards and 11 teachers wanted more direct modeling and instruction on the application of engineering and engineering practices as a content area and within curricular design. For example, Ms. Miller, a fourth grade teachers stated that they had “already incorporated a lot of design challenges (an engineering aspect) into our unit” but for professional development “more knowledge of engineering projects that are possible” was needed. The focus on content and application mirrors teachers’ comments teachers on STEM integration in the second TWS.

To conclude, there were several broad themes concerning teachers’ perceptions of integrated STEM engineering and engineering practices interwoven within the TWS. While the majority of teachers, 12 out of the 14, could identify the conceptual and integrative differences between the current K-8 Arkansas Science Frameworks and the NGSS standards, the teachers’ need to have more exposure and instruction on NGSS was clearly stated. This was not surprising given the teachers' professional accountability towards teaching to the standards within the classroom and in curriculum delivery. As the current Arkansas standards are not integrative, nor do they have a STEM focus, teachers wanted more direct instruction and modeling of both the content and integrative practices the professional development training to obtain greater subject matter knowledge in engineering and engineering practices but also in topic-specific instructional pedagogical knowledge to bring integrative STEM into their classrooms. Furthermore, they also wanted more training and resources so that they could begin to expand their current levels of expertise and develop other units of study for their classrooms.

Identification of Engineering and Engineering Practices

Approximately 15 minutes at the end of the focus group interviews involved the teachers individually analyzing their November curriculum unit and their self-selected best STEM lesson for evidence of engineering in the documents. This was done in order to gather information about Research Subquestion 5: "Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate engineering and engineering practices?"

Following printed directions, each teacher was asked to highlight the engineering found in the curriculum unit and within their own STEM lesson. Teachers were instructed to write a key word or phrase near the highlights providing a rationale for the selection. Using Post-It notes, the teachers did four Think-Write (TW) commenting on how they determined what engineering *was present* in each of the documents as well as how engineering *was integrated*. Teachers did not share their results with each other as this activity was designed to corroborate what the teachers stated in the interviews and other Think-Write-Shares.

To order to analyze the teachers' perception of engineering and engineering practices within the two documents, three steps were taken. First, the TWs were entered into an Excel document to help evaluate the kinds of design thinking, engineering habits of mind, and perceptions of engineering the teachers held. Second, the text of the highlighted sections within the individual teacher curriculum documents and the lesson plans were scanned for highlighted key words and entered into an Excel document. The key words were consolidated by grade and then numerically coded to delineate engineering, science, or mathematics followed by bottom up coding of the data based on semantic similarities (Hatch, 2002). Six frequency charts were then constructed. Third, individual units were analyzed using a similar process to that used in the archival curriculum documents wherein the standards, the curriculum unit and the teacher STEM lesson plan were studied regarding the presence of engineering as determined by the Committee on K-12 Engineering Education (2009a).

At this point, the need to delineate a continuum of teacher perception of engineering beyond engineering as a body of knowledge or a system of design became apparent. The Massachusetts Department of Education (2006), stipulated eight steps within its engineering design loop: identify a need or want, research the need, develop possible solutions, select the best solution, construct a prototype, test and evaluate the solution, communicate the results, and redesign. The addition of Dym's requirements of engineering design is used to "achieve clients' objectives or users' needs while satisfying a specified set of constraint" are important additions to the list (Brophy et al., 2008, p. 372). Further delineating the design thinking into more discrete sub-categories was needful. Stage 1 entailed the application of s*ome* of the design steps, but without an identification of a want or need, with a heavy focus on the middle steps of design, build, test and modify. Stage 2 involved using a number of the design steps in a linear fashion with the explicit statement that engineering is the application of known science or mathematics. Stage 3 applies Dym's additional modifications to iterative applications of all the design stages within the curriculum lesson. Stage 4 applies Dym's additional modifications to iterative applications of all the steps, the application of science or mathematics understandings, with a discrimination between engineering design and technological design.

Once these stages were delineated, then the analysis of the documents proceed to locating the presence of the engineering habits of mind (systems thinking, creativity, optimism, collaboration, communication, and ethical considerations) that the teachers *actively highlighted* within the curriculum unit, in the STEM lesson, or was written in the TWs.

In the following paragraphs, the results of the key word analysis are shown followed by a discussion of each of the four curriculum units. After that, an analysis of the results, in total, is presented.

Key Word Analysis. After conducting a key word analysis of the 334 highlighted words and coding phrases found within the 14 highlighted curriculum units and personal STEM lessons, Table 47 through Table 52, indicate the range of teacher perceptions of engineering within the units.

Table 47
Overall Categorization of Engineering Key Words

Key Word Category	**Frequency**
Engineering as Design Stages	196
Science Content	59
Engineering as Unit of Design Process	33
Science Practices	31
Mathematics Practices	15
Total	334

Table 48
Engineering as a Unit of Design Process

Design Process Key Words	**Frequency**
Design Challenge	16
Design Loop	13
Engineering Loop	4
Total	3

Table 49
Engineering as Design Stages

Design Stages Key Words	**Frequency**
Engineering as Design Stages	
Design	64
Modify	35
Build/Create/Construct	33
Evaluate/Assess	11
Prototype/Model	10
Constraints	9
Test/Retest	9
Explain/Justify	9
Research	5
Solution	5
Define a Problem	3
Report	3
Total	196

Table 50
Science Content Topics

Science Content Key Words	**Frequency**
Force and Motion	20
Newton’s Laws	4
Weather	4
Total	31

Table 51
Science Practices

Science Practices Key Words	Frequency
Predict	6
Observe	5
Collect Materials	5
Conduct Investigations	5
Hypothesize	3
Draw Conclusions	3
Goals	2
Evidence	1
Variables	1
Total	59

Table 52
Mathematics Practices

Math Practices Key Words	Frequency
Measure	8
Chart and Record	5
Use Tools	2
Total	15

Out of a total of 334 highlighted words, the *Engineering as Stages of Design* in Table 3, made up 59% of the total responses. The most pervasive being the *designing a solution*, *building*, and *modifying a solution* stages. These highlights alone made up 40% of the total overall entries. There was a relative lack of highlighting at the extremes of the design stages, in that *defining a human problem* and *researching towards a solution* stages made up 2.4% of the total. *Finding a solution* and *reporting the results* was also indicated 2.4%. Teachers highlighted words or phrases that could be categorized within *Engineering as a Unit of Design* 10% of the total entries.

Science and mathematical principles provide the theoretical foundations for engineering and were part of the STEM content of the curriculum unit (Brophy et al., 2008). Science domain content was highlighted 9% of the time while mathematical theory was not evident. Instead science, and mathematical process skills, were used within scientific inquiry, made up 22% of the total highlighting (Padilla, 1990).

In sum, teachers favored words and phrases that related to engineering as design stages over half the time, as a system of design a tenth of the time, and as a domain body of knowledge none of the time. Science and mathematics were highlighted approximately two tenths of the time.

Eastside

In reviewing Stage 1 of the four Eastside teachers' curriculum unit, three teachers indicated the skills section as containing elements of engineering. Common to all three were the following: design/create an airplane hangar that can withstand outside forces; plan and conduct an investigation/carry out tests; and construct an investigation and design a solution. One teacher highlighted make observations and measurements while another marked investigate relationships between force and motion. Table 53 denotes which lesson individual teachers marked as containing engineering.

The teachers designated 19 lessons, out of a possible 40, as having engineering. The lessons were intradisciplinary cellular four times, interdisciplinary sequenced dyad seven times, and in an interdisciplinary sequenced triad eight times.

The three teachers correctly highlighted engineering within engineering lessons five times and correctly identified non-engineering lessons 18 times. Consequently, teachers correctly identified engineering 23 out of 40 possible lessons, or 57.5 % of the time.

Teachers indicated technology for engineering, when it was a dominant content area, seven times, ELA two times, and science once. They also designated engineering for a shared dominance of science and technology four times. They did not indicate engineering when it was present as a dominant areas three times out of the possible 40. In short, teachers did not correctly identify engineering 17 times or 42.5% the total.

Table 53
Eastside Engineering Designations Within Grade Level Curriculum Unit

Curriculum Lesson	**Anderson**	**Jones**	**Moore**	**White**
D 1 Interdisciplinary Sequenced SCIENCE-*ela*				
D 2 Intradisciplinary Cellular SCIENCE				
D 3 Intradisciplinary Cellular SCIENCE				
D 4 Interdisciplinary Sequenced TECHNOLOGY-science-*mathematics*	X	X	X	X
D 5 Interdisciplinary Sequenced SCIENCE-TECHNOLOGY	X	X	X	X
D 6 Intradisciplinary Cellular SCIENCE		X		
D 7 Interdisciplinary Sequenced ENGINEERING-technology-*science*	X	X		X
D 8 Interdisciplinary Sequenced TECHNOLOGY- *ela*		X	X	X

Table 53 (Cont.)
Eastside Engineering Designations Within Grade Level Curriculum Unit

Curriculum Lesson	Anderson	Jones	Moore	White
D 9 Intradisciplinary Cellular ENGINEERING	X	X		
D 10 Intradisciplinary Cellular ELA		X		X

Note: D= Day. Capitals indicates dominant content domain(s), lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role.

Eastside Engineering and Engineering Habits of Mind. Overall, the Eastside teachers were in the beginning to middle stages of engineering conceptualization. Table 544, indicates where each teacher fell.

Table 54
Eastside Third Grade Teachers' Conceptualization of Engineering

Teacher	Body of Knowledge	Stage 1 System of Design	Stage 2 System of Design	Stage 3 System of Design	Stage 4 System of Design
Anderson		X			
Jones	X				
Moore			X		
White			X		

Ms. Anderson, Stage 1, was explicit in her TW that the grade level was sure to include, "…engineering lesson, which meant they had to design, create or make changes in the project" within their greater STEM unit. Two teachers were in Stage 2. In her Think-Writes, Ms. Moore stated that she looked for "key words that hinted towards the application piece" and that they "took their knowledge of the content taught and applied it with the engineering activities". She had the students follow a design, create, test, and explain sequence of engineering stages. Ms. White included slightly more design stages as she also included modify and retest in her highlighting. Interestingly, she saw a division between science and STEM as a whole as she stated on her integrative TW, “The STEM lessons were integrated into the bigger unit with force and motion in mind. We only used a STEM lesson when it was deepening their knowledge of force.”

However, Ms. Jones took a different tack, in that she comingled science inquiry, science practices, and engineering into a unique body of knowledge wherein the purpose of engineering was gain science knowledge. “I used multiple avenues to make sure the students ‘understand’ forces of motion, and they were able to design their way to understanding on their own through the concept of engineering”. She was consistent in her highlighting and on her TWs in what was to be included, the sequence, and how the specific sequence denoted that engineering was integrated. “Engineering was integrated [by the stages of] test, design, create, justify, evaluate, hypothesize, draw conclusions, construct”. Seemingly, Ms. Moore is substituting some steps of science practices with engineering practices within the larger domain of science inquiry.

There were only two engineering habits of mind indicated, collaboration and communication. Ms. White highlighted both within her curriculum unit and Ms. Jones repeated used the words justify, in terms of written or oral justification, in her coding.

Northside/Westside

Three teachers were involved in developing the third grade curriculum unit. However, the two Westside teachers opted to do a different end assessment during the course of teaching the lesson, substituting a version of the parachute drop introduced during the October 11 training, instead of the airplane that had originally been indicated. The teacher from Northside added a paired computer simulation of airplane flight prior to introducing a Bernoulli loop airplane for the end assessment. All the processes up to Lesson Five remained the same.

A second divergence between the two schools occurred in the timing of the lessons on the three lesson plans. While the November curriculum unit was finalized with a STEM lesson being taught once a week, the teacher's lesson plans indicate that the time was foreshortened wherein multiple lessons were taught within a week. The date on the Northside lesson plan included that last four lessons of the unit and was taught during the week of September 8. The Westside teacher's lesson plans indicate that the last three lessons were actually taught during one week, from October 20 to October 24. The rationale for not changing the timing on the November unit was not stated during the interview.

Table 55 indicates the highlighting of the curriculum unit with the exception of Ms. Johnson's whose was incomplete because, as written in her integrative TS, she wasn't "sure how to address this. Engineering was integrated because it is literally, a part of STEM. It is only natural that engineering is integrated into the lessons b/c w/o [abbreviations in the original] it, it's not STEM." Because of the shifts in content and timing, the table diverges at Lesson 6.

Table 55

Northside/Westside Engineering Designations Within Grade Level Curriculum Unit

Curriculum Lesson	Johnson	Miller	Wilson
Joint Curriculum Lessons			
D 1 Intradisciplinary Cellular ENGINEERING		X	X
D 2 Intradisciplinary Cellular SCIENCE			
D 3 Interdisciplinary Sequenced (dyad) SCIENCE-ENGINEERING			
D 4 Intradisciplinary Cellular SCIENCE			

Table 55 (Cont.)

Northside/Westside Engineering Designations Within Grade Level Curriculum Unit

Curriculum Lesson	Johnson	Miller	Wilson
Joint Curriculum Lessons			
D 5 Interdisciplinary Sequenced (triad)) SCIENCE-technology-*engineering*			
Northside			
D 6 Westside Interdisciplinary Sequenced (dyad) SCIENCE-ELA			X
D 7 Northside Interdisciplinary Sequenced (dyad) ELA-TECHNOLOGY (Computer Simulation)			X
D 8 Northside Intradisciplinary Cellular SCIENCE			
D 9 Northside Interdisciplinary Sequenced (triad) TECHNOLOGY-science-*ela*			X
Westside			
D 6 Westside Intradisciplinary Cellular TECHNOLOGY	X	X	
D 7 Westside Intradisciplinary Cellular TECHNOLOGY	X	X	
D 8 Westside *Interdisciplinary Sequenced (triad)* *TECHNOLOGY-mathematics*	X	X	
D 9 Westside Interdisciplinary Sequenced (dyad) TECHNOLOGY-ELA	X	X	

Note: D=Day. Capitals indicates dominant content domain(s), lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role. The last three lessons were taught within the same week by the Westside teachers.

Ms. Wilson highlighted four lessons as engineering out of her modified nine lesson unit. Of those, she attributed engineering to either science or technology when those domains were coupled with each other or ELA using interdisciplinary sequenced dyad or triad forms. She indicated engineering one time in an intradisciplinary cellular lesson. The two Eastside teachers, Ms. Miller and Ms. Johnson, highlighted nine lessons as containing engineering out of a possible eighteen lessons in their two combined curricular units. Of those they attributed engineering to technology eight out of the eighteen lessons in an interdisciplinary sequenced dyad or triad forms and once to an engineering lesson intradisciplinary cellular form.

When all the possible lessons were combined, 27 possible sessions, the three teachers indicated engineering was present within lessons that were intradisciplinary cellular six times, interdisciplinary sequenced dyad four times, and interdisciplinary sequenced triad three times.

The three teachers correctly highlighted engineering within engineering lessons two times and correctly did not select a non-engineering lessons 10 times. Consequently, teachers correctly identified engineering 12 out of 27 possible lessons, or 44.5 % of the time.

Teachers indicated technology for engineering, when it was a dominant content area, ten times and science as engineering one time. Teachers also did not indicate engineering when it was present as a dominant areas four times out of the possible 27. In short, teachers did not correctly identify engineering 15 times or 55.5 % of the total.

Northside/Westside Engineering and Engineering Habits of Mind. The three teachers from Northside and Westside ranged in their approaches to engineering. Table 56 delineates their approaches.

Table 56
Northside/Westside Third Grade Teachers' Conceptualizations of Engineering

Teacher	Body of Knowledge	Stage 1 System of Design	Stage 2 System of Design	Stage 3 System of Design	Stage 4 System of Design
Johnson				X	
Miller			X		
Wilson			X		

Ms. Wilson saw engineering as linear sequence of steps based on prior scientific inquiry. In her integrative TW, Ms. Wilson stated that “engineering was used in combination with math and science knowledge. All 3 had to be used to accomplish the task”. For the most part, however, she confounded engineering with a science inquiry activity designed to help her students understand force and motion which didn’t develop a process or product. This was evidenced within her STEM lesson where she had her students derive a hypothesis and develop science inquiry procedures to see the effects of force on the Bernoulli loop plane, procedures that Ms. Wilson had highlighted as engineering (Householder & Hailey, 2012).

The two Westside teachers, Ms. Johnson and Ms. Miller, had a very clear sense idea of the process of a design challenge but the process was applied to a technological design challenge rather than an engineering one. Technological design challenges involve solving problems through the development of a tool, in this case a parachute, and seeing how that tool is used (Karwowski, 2005). Ms. Miller focused on design stages of create, build, research, prototype, modify, test, and explain. Ms. Johnson, however, understood the iterative process within the design system and how it was informed by the science. In her engineering TW, she stated, “Engineering is present in some mini-lessons prior to the design challenge (testing how motion can be charted in a moving object-earlier in this unit) and in this design challenge-the student completed a couple of cycles of the design loop.” What is noted in her TW responses is that she did not use the term engineering design loop but always refereed to the process by the truncated form. Regarding engineering habits of mind, like the other third grade team, communication was highlighted by two teachers and collaboration by one.

Fourth Grade

In reviewing Stage 1 within the curriculum unit of the two fourth grade teachers, one teacher highlighted the following skills: organize data in tables and charts, construct and read instruments to collect weather data and identify the variables that affect investigations. Both teachers taught the original curriculum unit as it was written and in the same sequence. Table 57, shows the lessons that the fourth grade teachers indicated included engineering.

Table 57
Fourth Grade Engineering Designations within Grade Level Curriculum Units

Curriculum Lesson	Davis	Taylor
D 1 Intradisciplinary Connected SCIENCE		
D 2 Interdisciplinary Sequenced (dyad) SCIENCE -ELA		
D 3 Interdisciplinary Sequenced (dyad) ELA-TECHNOLOGY		
D 4 Interdisciplinary Sequenced (dyad) TECHNOLOGY-ela		
D 5 Interdisciplinary Sequenced (dyad) SCIENCE ELA	X	X
D 6 Intradisciplinary Connected SCIENCE-ela		
D 7 Integrated-Webbed BLENDED STEM		
D 8 Integrated-Webbed BLENDED STEM		
D 9 Integrated-Webbed BLENDED STEM		

Table 57 (Cont.)

Fourth Grade Engineering Designations within Grade Level Curriculum Units

Curriculum Lesson	Davis	Taylor
D 10 Interdisciplinary Shared (dyad) SCIENCE- TECHNOLOGY		
D 11 Interdisciplinary Shared (dyad) SCIENCE- TECHNOLOGY		X
D 12 Intradisciplinary Connected SCIENCE	X	X
D 13 Interdisciplinary Shared (triad) ENGINEERING-science-mathematics	X	X
D 14 Interdisciplinary Shared (triad) ENGINEERING-science-mathematics	X	X
D 15 Interdisciplinary Shared (triad) ENGINEERING-science-mathematics		X
D 16 Intradisciplinary Connected ENGINEERING		X
D 18 Intradisciplinary Connected ENGINEERING		X

Note: D= Day. Capitals indicates dominant content domain(s), lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role.

Out of 32 possible lessons, the two teachers indicated engineering was present in a lesson that was intradisciplinary connected three times, in an intradisciplinary sequenced dyad two times, within intradisciplinary cellular lessons six times, using interdisciplinary sequenced dyad four times, in an interdisciplinary sequenced triad lesson three times, and within an interdisciplinary shared triad form four times.

The two teachers correctly highlighted engineering within engineering lessons five times and correctly didn't select a non-engineering lessons seven times. Consequently, teachers correctly identified engineering 12 out of 32 possible lessons, or 37.5 % of the time.

Teachers indicated science for engineering, when it was a dominant content area, two times, science and ELA with shared equal dominance two times, and science and technology three times. It is important to note that both teachers did not identify engineering as being part of the fully integrated BLENDED STEM lessons six times. Teachers also did not indicate engineering when it was present as a dominant area seven times. In short, teachers did not correctly identify engineering 20 times or 63.5 % of the total.

Fourth Grade Engineering and Engineering Habits of Mind. The two fourth grade teachers were either in Stage 1 or Stage 2 in their perceptions of engineering as a system of design in Table 58.

Table 58
Fourth Grade Teachers Conceptualizations of Engineering

Teacher	Body of Knowledge	Stage 1 System of Design	Stage 2 System of Design	Stage 3 System of Design	Stage 4 System of Design
Davis		X			
Taylor			X		

Mr. Davis had a very specific perception of engineering in that engineering was comprised of four stages, "build, test, assess, and modify", in terms of "students making something or working and reacting to their decisions". He made minimal highlights in his unit and lesson plan, consequently analysis of his perception of engineering rests with the statements above.

Ms. Taylor was precise in how she designated her engineering sequence, "research, design, test, modify, test again, record data, and present findings" on all her TWs. In her curriculum unit and self-selected lesson plan, however, she applied engineering to three different applications, two non-engineering and one engineering. The first non-engineering application was within technological design loop, wherein the students applied their understanding of how different weather instruments and planes functioned. In the cased of the paper airplanes, after learning about how different types functioned, the students modifying teacher pre-selected types to see the effect of the student modifications during flight trials (Karwowski, 2005). The second non-engineering application was during a science inquiry investigation, within her multiday STEM lesson plans, where she had her students derive a hypothesis and make evidence based predictions concerning how their modified aircraft would fly during two different (inside and outside of the classroom) environmental conditions. Later in the lesson, however, when the students had to apply this knowledge of science and make further modifications based on weather conditions (first day/next day) Ms. Taylor correctly identified engineering design within an engineering lesson (Householder & Hailey, 2012). In terms of engineering habits of mind, both teachers highlighted cooperative groups within their curriculum units and lesson plans.

Fifth Grade

There were five fifth grade teachers from all three schools. Four of the teachers completed the curriculum unit. Mrs. Jackson started the unit with her gifted students but stopped after the first lesson and did not continue nor did she bring a lesson to the interview. Within the curriculum unit's Stage 1, two teachers highlighted three understandings: successful thinkers utilize others' ideas to enrich their own, balanced and unbalanced forces affect the motion of an object, and changes in energy are caused by different forces. Two teachers also highlighted three skills: analyze the effects of force on motion, experiment with energy and forces, examine multiple examples of change. Table 59 shows the lessons that the fifth grade teachers indicated included engineering.

Table 59
Fifth Grade Engineering Designations within Grade Level Curriculum Units

Curriculum Lesson	Brown	Jackson	Martin	Smith	Williams
D 1 Intradisciplinary Cellular SCIENCE			X		
D 2 Intradisciplinary Cellular SCIENCE			X	X	X
D 3 Intradisciplinary Cellular SCIENCE	X	X	X	X	
D 4 Interdisciplinary Shared (dyad) SCIENCE-*ela*			X		
D 5 Interdisciplinary Shared (dyad) SCIENCE-TECHNOLOGY	X	X	X		
D 6 Interdisciplinary Shared (dyad) SCIENCE-*ela*	X		X		
D 7 Interdisciplinary Shared (dyad) SCIENCE-TECHNOLOGY	X	X			X
D 8 Interdisciplinary Shared (dyad) SCIENCE-TECHNOLOGY	X	X			X
D 9 NA					
D 10 Interdisciplinary Shared (triad) ELA-SCIENCE- *mathematics*		X		X	

Note: D=Day Capitals indicates dominant content domain(s) lower case a supporting content domain, and lowercase italics indicate a content domain in a minor role. There were 45 possible lesson, disregarding the lessons in Day 9. Day 9 has a NA as it was a review or catch up day depending on the class.

The five teachers indicated that engineering was present in intradisciplinary cellular lessons eight times, an interdisciplinary shared dyad lessons 11 times, and within interdisciplinary shared triad lessons two times.

Engineering and engineering design was not present in the unit. The teachers correctly did not indicate engineering in non-engineering lessons 22 times. Consequently, teachers correctly did not attribute engineering 49% of the total time.

Teachers indicated science for engineering, when it was a dominant content area, ten times, when science and ELA with shared equal dominance twice, and science and technology with equal dominance 11 times. Although engineering and engineering design were not present in the unit, technological design and technology within science inquiry were. Consequently, teachers misidentified other lessons for engineering 23 times or 52% of the total.

Fifth Grade Teachers Engineering and Engineering Habits of Mind. Overall, the fifth grade teachers were either in Stage 1 or Stage 2 in their perceptions of engineering as a system of design. Table 60, below, outlines individual teacher levels.

Table 60
Fifth Grade Teachers Conceptualizations of Engineering

Teacher	Body of Knowledge	Stage 1 System of Design	Stage 2 System of Design	Stage 3 System of Design	Stage 4 System of Design
Brown		X			
Jackson		X			
Martin		X			
Smith			X		
Williams			X		

Ms. Brown stated that application of science and “what they were learning to the design challenge” to indicate engineering in her curriculum unit. She highlighted research, create, and design in her unit. Ms. Williams stipulated that engineering is “designing, creating, meeting criteria, modifying, and testing…and that engineering is a verb or knowledge of a creative process—mental or physical". Ms. Martin provided very few highlights and codes to understand her process, however in her engineering integration TWs, she stated that engineering was "developed by seeing Newton's laws being carried out" and she include research, create, and design in her coding. It is important to note that the lessons the three teachers highlighted were either science investigations or science inquiry using technological design thinking to test out variables within the investigation.

The remaining two teachers did not highlight as many of the lessons in the unit because they clearly identified the lessons as science. In the ones they did highlight, it was in regards to using technology in a design loop. In reviewing the unit, Ms. Smith stated in her engineering TWS, that the process of engineering was "using what they knew about force and motion and the materials they were using, students had to design and modify what they were doing through the design loop." Ms. Williams also stated in her engineering TWS, that engineering was present when "the students used practices that required them to build, construct, modify… according to that their goal was". Both teachers wrote side notes to link the science to engineering. Ms. Smith stated that her Galileo Loop lesson wasn't "so much based on the design loop but it did build a foundation for the entire unit" and Ms. Williams wrote a side note about the end performance assessment that "speed, distance and weight are not really engineering but that engineering processes" were used to design the plane. In terms of engineering habits of mind, only one teacher highlighted an attribute-creativity.

Summary

In June of 2014, the 14 Project Flight teachers demonstrated their understanding of some of the core syntactical structures of engineering and engineering practices through the highlighting and coding of their grade level curriculum unit and their self-selected STEM lesson. Table 61, Table 62, and Table 633 describe the integrative type of lesson teachers selected as containing engineering; the content domains that were designated as engineering; and the teachers' overall conceptualizations of engineering either as a body of knowledge or as modified series of engineering design steps.

Table 61 identifies the integrative type of lessons the teachers highlighted. Within the table, the word "dominant" is a place holder for where engineering was indicated within a given lesson plan regardless whether the lesson was actually engineering or not.

Table 61
Overall Teacher Perceptions of the Kinds of Engineering Integration

Integration Types	**3E**	**3NW**	**4**	**5**	**Total**	**%**
Intradisciplinary Cellular DOMINANT	4	6		8	18	28%
Interdisciplinary Shared (dyad) DOMINANT +OTHER			3	11	14	22%
Interdisciplinary Sequenced (dyad) DOMINANT +OTHER	7	4	3		13	20%
Interdisciplinary Sequenced (triad) DOMINANT -other-other	8	3			11	17%
Interdisciplinary Shared (triad) DOMINANT-other-other			4	2	6	9%
Intradisciplinary Connected DOMINANT			3		3	4%

The teachers highlighted engineering in a lesson plan when it was perceived to be the dominant subject domain in the lesson or when it shared equal dominance with another subject in an interdisciplinary lesson. Teachers did not highlight engineering in a lesson plan in which engineering took a supporting or minor role to another subject. In terms of integration, teachers highlighted 31% of the interdisciplinary sequenced lessons, 31% of the interdisciplinary shared lessons, 28% of the intradisciplinary cellular lessons, and 4% of the intradisciplinary connected lessons.

In Table 62, teachers' correct identification of engineering and misidentification of other STEM domains as engineering are indicated.

Table 62
Overall Teacher Identification of Engineering Within Curriculum Units

Integration Types	3E	3NW	4	5	Total	%
Correct Lesson Selection						
OTHER	18	10	7	22	57	40%
ENGINEERING	5	2	5		12	8.%5
Incorrect Lesson Selection						
TECHNOLOGY-SCIENCE	4		3	11	18	13%
TECHNOLOGY	7	10			17	12%
SCIENCE	1	1	2	10	14	10%
ENGINEERING	3	4	7		14	10%
BLENDED STEM			6		6	4%
SCIENCE-ENGLISH			2		2	1.5%
ENGLISH	2				2	1.5%

Teachers correctly identified engineering in lessons and correctly identified non-engineering lessons 48% of the time. Teachers misidentified lessons containing science, technology, or science and technology as dominant subjects as engineering in 38% of the lessons. Teachers did not identify engineering when it was the dominant subject or within BLENDED STEM within 14% of the lessons.

Table 63 amalgamates all the Project Flight teachers' perceptions of engineering as indicated by the highlighting and coding used within their individual curriculum documents.

Table 63
Overall Teacher Perceptions of the Structure of Engineering

Grade	Body of Knowledge	Stage 1 System of Design	Stage 2 System of Design	Stage 3 System of Design	Stage 4 System of Design	Total
3E	1					1
3E		1	2			3
3NW			2	1		3
4		1	1			2
5		3	2			5
Total	1	5	7	1		14

In sum, teachers identified lessons as engineering when some form of design loop was present. The loop could be embedded within science inquiry, be evident as a sequence of technological design stages, or, most infrequently, during engineering design stages during the end performance assessment.

Intradisciplinary integration made up 21% of the lessons indicated by the teachers, with the cellular form being highly favored. Interdisciplinary integration lessons are lessons of the most traditional kind. The content domain is taught in isolation and the purpose is to have students learn the discrete concepts and ways of thinking bound within the subject (Fogarty, 2009, pp.22-23). For teachers, whose understanding of aviation STEM has the potential to be quite topical, this kind of lesson allows for expertise within a narrow band of pedagogical content knowledge (Appleton, 2008).

The two most prominent sub-forms of interdisciplinary integration designated by teachers were lessons that sequenced or shared dyad and triad forms. Sequenced integration within the lessons was a beginning integrative mode using two or three STEM domains. There was limited articulation between the domains as the teaching of the first domain informed the understanding of the following domains. The design intent was to help students make better sense of STEM domains which could more conceptually be connected to each other (Fogarty, 2009). In the shared lessons, common ideas embedded within each of the different STEM domains used an inductive approach integration. This familiar, and common, integrative form was used to facilitate the generalization and transfer of student STEM understanding between content areas (Fogarty, 2009).

Overall, there seemed to be teacher engineering design process understanding that encompassed fragmented application of a few of the steps by five teachers at Stage 1 to a near coherent conceptualization of engineering design by 1 teacher at Stage 3 (Stage 1: 29%, Stage 2: 50%, Stage 3:7%, and Stage 4:0%). One teacher did describe engineering as a domain body of knowledge. Yet, her rationale for doing so indicated a combinatorial misidentification of science and engineering practices. Consequently, the six teachers—Stage 1 teachers and the teacher mentioned above—demonstrated a limited identification of engineering within the lessons, by focusing specifically on the steps in a design, build, test and modify sequence. This indicates a low familiarity with, and limited conceptualizations of, engineering and design processes (Hsu et al., 2011). The seven teachers at Stage 2, seemed to linearly incorporate a greater number of the engineering design stages while also expressing that engineering involves applying already known science concepts. Only one teacher was at Stage 3. This teacher conceptualized all the aspects of Stage 2 and saw engineering as a series of iterative applications throughout the whole process of design. There were no teachers at Stage 4, wherein the subtle differences between engineering and technological design stages was understood and applied appropriately (Karwowski, 2005). Generally, teachers very rarely identified any engineering habits of mind. Overall, there were six instances of group collaborative work, two of communication in the form of presentations, and only one of creativity.

Fundamentally, over the course of the professional development, the teachers concentrated on gaining the engineering pedagogical content knowledge aspects of integrative engineering instructional strategies with some of the syntactical and substantive structures of engineering as engineering relates to science and technology. However, the teachers seemed unaware of the deeper subject matter understandings concerning the noted differences between engineering and technology as well as the importance of the engineering habits of mind overarching engineering dispositions (Viiri, 2008).

Quantitative Data

Introduction. Quantitative data collection and analysis were required to answer research Subquestion 7: Was there a change in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum during the course of STEM professional development? The data concerning the changes of efficacy over the span of professional development training were collected in three ways. Teacher perceptions of efficacy after a week of professional development were collected from the Likert scores of six days of summer exit cards given in June of 2014. Longitudinal perceptions of efficacy were obtained from two sources. The first of these was from four STEM-TEBI administrations, using the first 10 questions of the test, within a calendar year. The second source was three sets of Likert scale scores from Project Flight Pre/Posttest Questions 9 and 10 concerning teachers' perceptions of their own familiarity with NGSS and implementation of STEM in the classroom. The null and alternative hypothesis for the Subquestion 7 were as follows:

Null hypothesis (H_0): Over the course of the STEM professional development, there is no significant difference, at the $p = .05$ level, in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum.

Alternative hypothesis (H_a): Over the course of the STEM professional development, there is significant difference, at the p = .05 level, in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum.

Exit cards. Three sets of paired exit cards were used for statistical analysis of. Likert scores of the study's 14 participants. Due to missing data cards within individual sets, descriptive statistics and unpaired *t*-tests were performed on the exit cards using SPSS. This allowed me to see if there would be a statistical difference in teachers' confidence levels due to the professional development training regarding teachers' confidence in applying Next Generation Science Standards, applying STEM in the classroom, and writing STEM lessons using UbD. Confidence in differentiation for the needs of the ELL in a STEM classroom, which was only administered once, was not included. The first exit slip in each set was used for the pretest and the second for the posttest.

Exit Card Set One analyzed the data for Days 1 and 5 involved teachers' confidence in applying the Next Generation Science Standards in their classrooms after a week of summer training. The NGSS implementation confidence scores rose significantly from Pre (M = 2.50, SD = 1.09, Range = 1-5) to Post (M = 3.55, SD = 0.93, Range = 2-5), t (23) = 2.53, two-tailed p < .02. The NGSS confidence scores are summarized in Table 64 and in Figure 7 .

Exit Card Set Two analyzed the data for Days 1 and 6, which measured teachers' confidence in applying STEM in the classroom, also rose significantly from Pre (M = 2.64, SD = 0.84, Range = 1-4) to Post (M = 3.73, SD = 0.79, Range = 2-5), t (23) = 3.28, two-tailed t-tests p < .003. The STEM application confidence scores are summarized in Table 64 and in Figure 7.

Exit Card Set Three analyzed the data for Days 3 and 7, which measured teachers' confidence in writing STEM lessons using UbD, also rose significantly from Pre (M = 2.86, SD

= 0.66, Range = 2-4) to Post (M = 3.6, SD = 0.84, Range = 3-5), t (22) = 2.4, two-tailed t-tests p < .024. The STEM writing application confidence scores are summarized in Table 64 and in Figure 8.

Exit Card confidence levels are summarized in Table 64, Figure , Figure , and Figure 8 below.

Table 64
Exit Card NGSS, STEM and Writing Confidence Scores

Statistic	**Exit Card Set One NGSS**		**Exit Card Set Two STEM**		**Exit Card Set Three Writing**	
	Pre	Post	Pre	Post	Pre	Post
Mean	2.50	3.55	2.64	3.73	2.85	3.6
N	14	11	14	11	14	10
SD	1.09	0.93	0.84	0.79	0.66	0.84
Min	1	2	1	2	2	3
Max	5	5	4	5	4	5

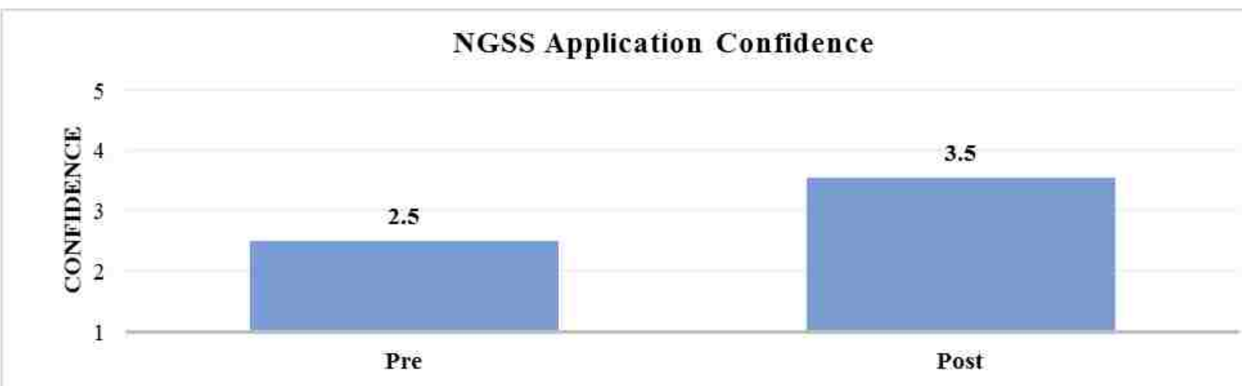


Figure 6. Exit Card Set 1. Pre and Post scores for NGSS application confidence. Error bars reflect standard error of the mean (SEM).

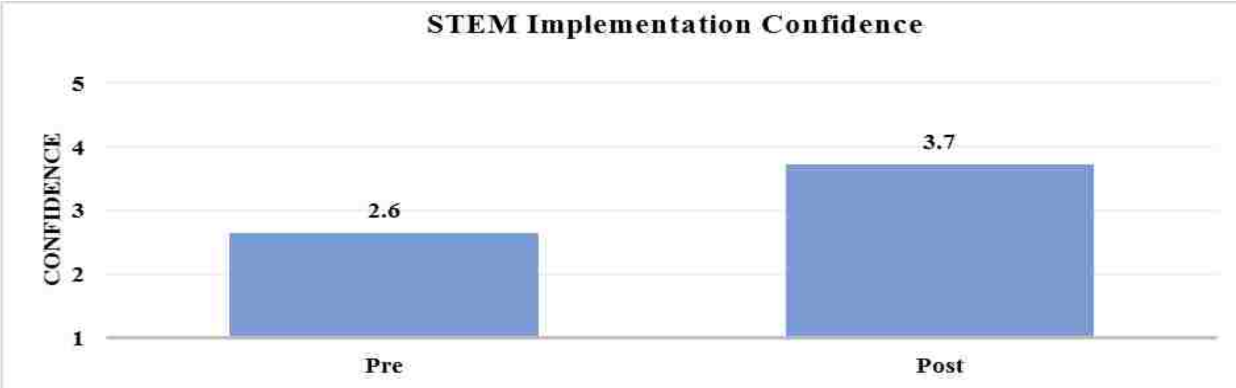


Figure 7. Exit Card Set 2. Pre and Post scores for STEM implementation confidence. Error bars reflect standard error of the mean (SEM).

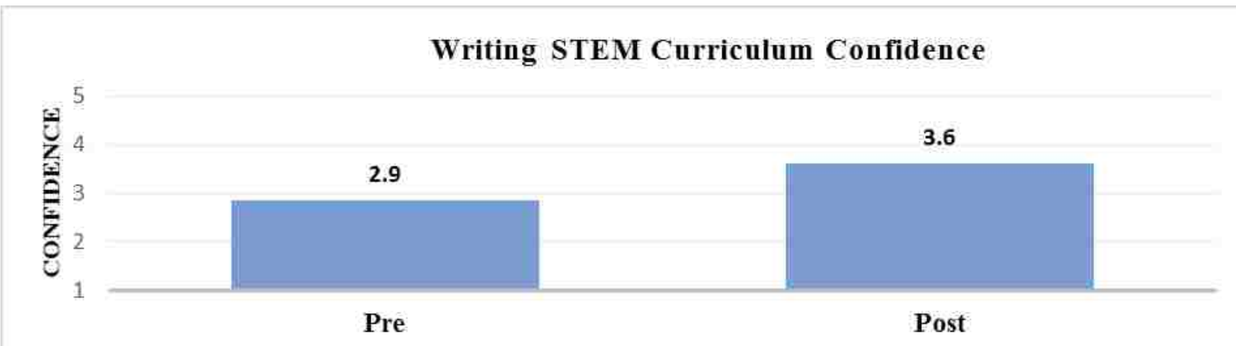


Figure 8. Figure Exit Card Set 3. Pre and Post scores for STEM Lesson Writing confidence. Error bars reflect standard error of the mean (SEM).

In sum, after a week of STEM professional development, the teachers' self-reporting of confidence levels concerning their knowledge of NGSS, implementation of STEM in the classroom, and writing STEM curriculum indicated significant, positive short-term effects of the professional development training.

STEM-TEBI.

The STEM-TEBI was given to the 14 participating teachers at four different times: (1) the pre-training test on June 9, 2014 prior to the start of the summer professional development; (2) Post1 on June 19, 2014 at the end of the summer professional development; (3) Post2 on November 8, 2015 approximately five months after the conclusion of the second follow up training day; and (4) Post3 on June 1, 2015 or June 2, 2015 nearly 12 months after the start of the original professional development training.

STEM-TEBI scores were contrasted using repeated measures ANOVA and showed statistically significant differences over time, ($F(3,10) = 5.58$, $p < .02$). The pre training scores, averaged 3.44 (SD = 0.47; Range 2.80-4.20), which was significantly lower than scores immediately following training (M 4.29, SD = 0.37, Range 3.50-4.40; $p < .001$), at the 5 month follow-up (M 3.88, SD = 0.62, Range 3.20-4.60; $p < .02$), and at 12 months follow-up (M 3.94, SD = 0.36, Range 3.40-4.40; $p < .02$). Scores immediately following training were significantly higher than scores at five month follow-up ($p < .03$) and at 12 months follow up ($p < .04$), while scores at 5 months follow-up and 12 months follow-up were similar to each other ($p = .78$). The STEM TEBI results are summarized in Table 65 and Figure 9. STEM-TEBI over Time. Error bars reflect standard error of the mean (SEM).

Table 65
STEM-TEBI Descriptives over Time

Statistic	**Pre**	**Post1**	**Post2**	**Post3**
Mean	3.53	4.05	3.85	3.91
N	14	14	13	14
SD	.37	.27	.42	.31
Min	2.80	3.50	3.20	3.40
Max	4.20	4.40	4.60	4.40

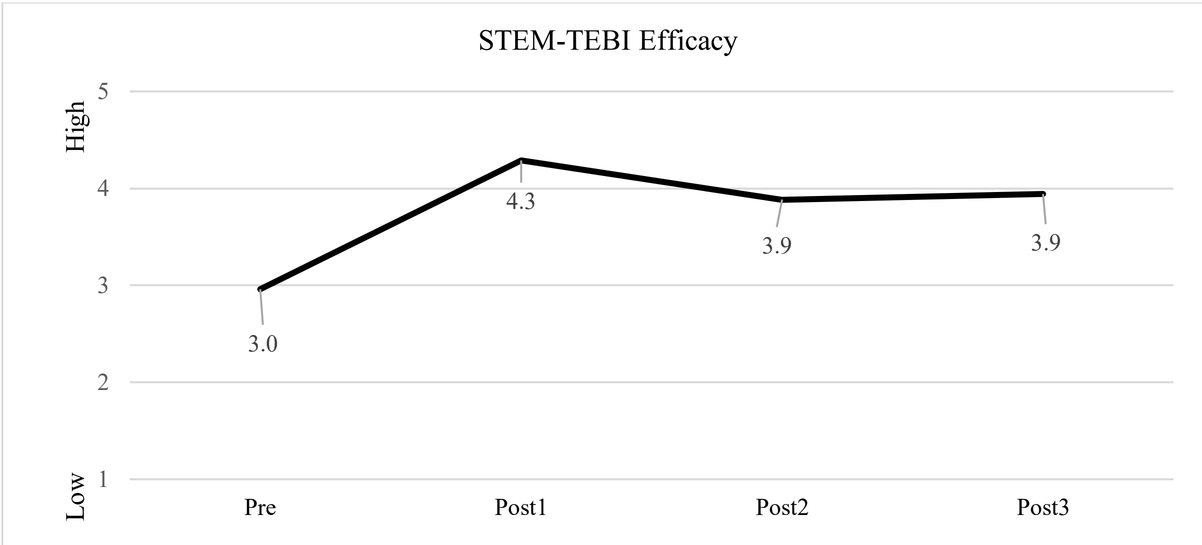


Figure 9. STEM-TEBI over Time. Error bars reflect standard error of the mean (SEM).

In conclusion, the STEM-TEBI data indicated significant long-term benefits with a peak in teacher self-efficacy at the conclusion of the summer professional development training and with a slight loss of confidence, but at near equal levels, for the semester after training itself.

Question 9 and question 10. Two sets of data were used for statistical analysis of the Likert scale scores of the 14 participants on Question 9 and Question 10 of the Project Flight Pre/Post Test. Question 9 stated, “On a scale from 1-5 (with 1 being least familiar), how familiar are you with the Next Generation Science Standards?” and Question 10 asked, “On a scale from 1-5 (with 1 being least familiar), how familiar are you with implementing STEM (Science, Technology, Engineering, and Mathematics) in the classroom?”.

Descriptive statistics and independent pairwise comparisons using SPSS were used to ascertain if there would be a statistical difference in teachers’ familiarity with NGSS and implementation of STEM in the classroom due to professional development. Data were collected from participating teachers at three different times: (1) the pre-training test on June 9, 2014 prior to the start of the summer professional development; (2) Post1 on June 19, 2014 at the end of the summer professional development; and (3) Post3 nearly 12 months afterwards on either June 1, 2015 or June 2, 2015 during the new data collection phase of this study. There was a Pre/Post Test given during the first follow-up training day in October of 2014, but because names were missing on the majority of the tests, the data were not included.

Question 9 involved teachers' familiarity with the NGSS, using a Likert scale, with 1 being least familiar and 5 being most familiar, found that after a week of summer training, the NGSS familiarity rose significantly from Pre (M = 1.35, SD = .74, Range = 1-3) to Post1 (M = 3.57, SD = 0.51, Range = 3-4) 95% Confidence Intervals for Difference of the Means -2.7 to -1.65, $p < .00$. There was a dip between the familiarity levels between Post 1 to Post2 (M=3.00, SD= .55, Range 2-4, and 95% Confidence Intervals for Difference of the Means .08 to 1.06), $p < .026$. However, when Post2 was compared to the Pretest scores, the teachers had retained a significant familiarity with the NGSS, $p < .00$, throughout the school year.

Question 10 involving teachers' familiarity with implementing STEM in the classroom, had a similar pattern of familiarity over time. Using a Likert scale of with 1 being least familiar and 5 being most familiar, found that after a week of summer training, STEM familiarity rose significantly from Pre (M = 1.71, SD = .82, Range = 1-3) to Post1 (M = 3.93, SD = 0.47, Range = 3-5) 95% Confidence Intervals for Difference of the Means -2.77 to -1.65, $p < .00$. There was a decrease in familiarity levels between Post 1 to Post2 (M= 3.36, SD= .63, Range 2-4), 95% Confidence Intervals for Difference of the Means, .135 to 1.00, $p < .014$. However, when Post2 was compared to the Pretest scores, the teachers had retained significant familiarity with the NGSS, $p < .00$, throughout the school year. The results for Question 9 and Question 10 are summarized in Table 66 and in Figure 10 and Figure 11.

Table 66
Question 9 and Question 10 Descriptives over Time

Statistic	**Question 9: NGSS**			**Question 10: STEM**		
	Pre	Post1	Post2	Pre	Post1	Post2
Mean	1.36	3.57	3.00	1.71	3.93	3.36
N	14	14	14	14	14	14
SD	.74	.51	.55	.82	.47	.63
Min	1	3	2	1	3	2
Max	3	4	4	3	5	4

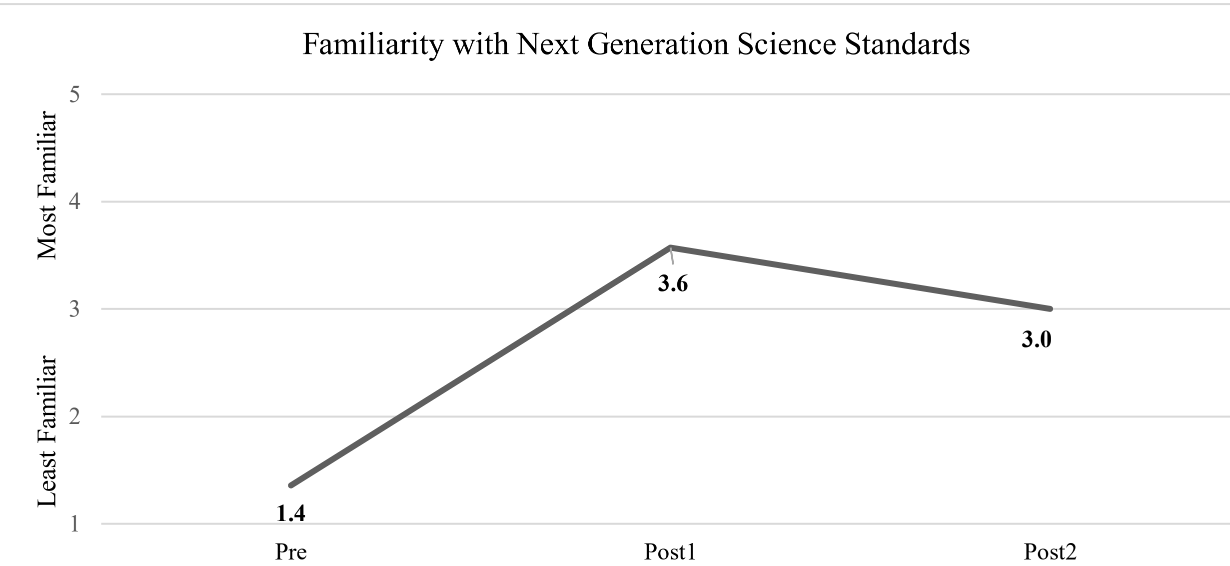


Figure 10. Familiarity with NGSS over Time. Error bars reflect standard error of the mean (SEM).

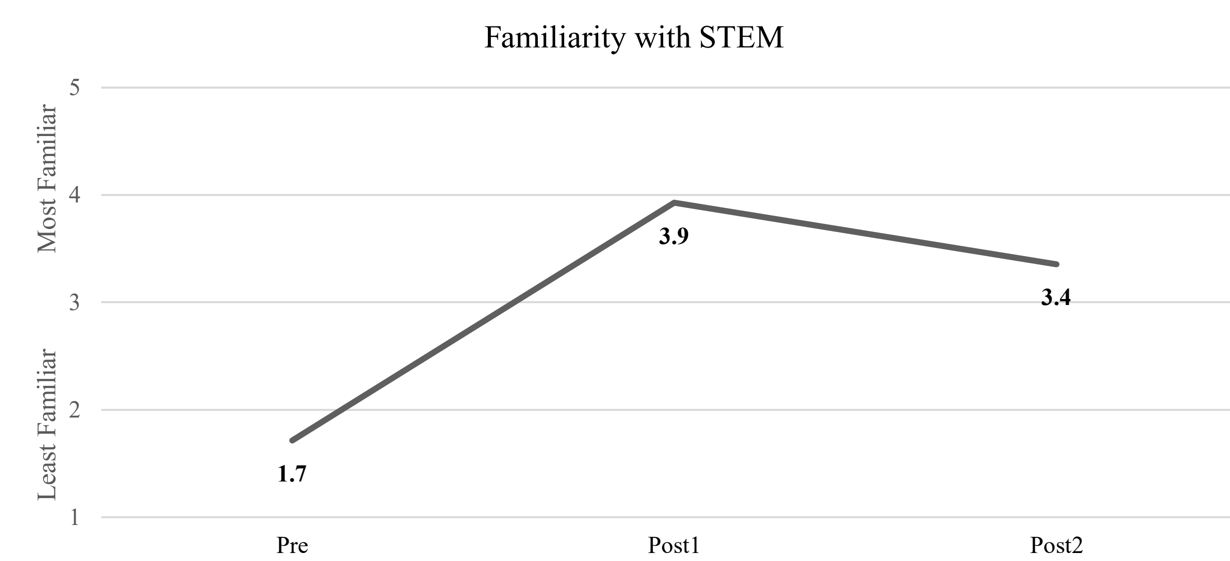


Figure 11. Familiarity with STEM over Time. Error bars reflect standard error of the mean (SEM).

In sum, teachers' perceptions of familiarity showed similar trends in the data over time, with the highest level of familiarity being at the conclusion of the summer professional development cycle, with a reduction in familiarity seven months later at the conclusion of the school year, but still showing a significantly positive familiarity with NGSS and implementation of STEM in the classroom when compared to familiarity prior to the start of the professional development. An interesting thing to note, is the slightly elevated familiarity of the teachers towards STEM activities over NGSS overall, indicating exposure to STEM outside the professional development training.

Conclusion. Data from all three sources (exit cards, STEM-TEBI, two PrePost questions [Question 9, and Question 10]) indicated significant, positive effects in teachers' confidence at the $p < .05$ over time. All three sources showed similar trends in the data, with the greatest gains in confidence and familiarity being obtained at the conclusion of the two-week summer professional development training.

Confidence and familiarity with NGSS and with STEM implementation, when triangulating the information, were confirmatory when analyzing post Exit Cards and the Post1 Question 9 and Question 10. Exit Card confidence in NGSS, with a mean score of 3.55, compared well Question 9's familiarity mean score of 3.57. Teachers did not indicate during the collection of the data if they had received further training in NGSS during the spring semester.

Concurrently, Exit Card confidence in implementing STEM in the classroom had a mean score of 3.93 which was similar to Question 10's familiarity score of 3.73. As there were no questions on the Project Flight Pre/Posttest specific to the writing of STEM curriculum, the data for Post Exit Card confidence in writing, which showed a significant positive change of $p < .025$, were not confirmed by quantitative means.

Levels in both in the STEM-TEBI and two questions dropped, however, during the first semester of teaching, which included two days of follow up training sessions, but held relatively stable during the second semester where there was no Project Flight STEM professional development training. Results of confidence and familiarity at the end of the second semester, nearly 12 months after the start of the STEM professional development, were still significantly higher than the pre-training scores with a significance level, $p < .03$, on the STEM-TEBI and to $p < .00$ level for both Question 9 and Question 10.

Based on the results of the quantitative data analysis, therefore, the null hypothesis which stated that there would be no significant difference in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum is rejected.

Chapter 5. Conclusions

The purpose of this study was to describe and understand the perceptions and approaches novice elementary engineering teachers take when designing curriculum units during integrated STEM professional development and through the subsequent teaching of the unit within their classrooms. As there is no well-established, canonical elementary engineering theoretical base, this research was undertaken to add to the few existing bodies of knowledge by describing the mental constructs and attitudes the teachers new to the subject domain use (Rocco & Plakhotnik, 2009).

The emergent socio-constructivist conceptual guide for the study was rudimentary in nature and based on current theoretical research in related areas: science teacher PCK, teacher self-efficacy and attitudes towards science, effective professional development theory, organizational development, and curriculum development. The focus of the research was to discern possible future avenues of integrated STEM professional development to help Arkansas elementary teachers develop engineering pedagogical content knowledge, as well as to support teachers' effective transition towards using NGSS which are due to be phased in during the 2016-2017 school year (Arkansas Department of Education, 2005). Figure 12, shows the conceptual framework relating the key areas of research to the theoretical foundations of each area was developed to guide the research.

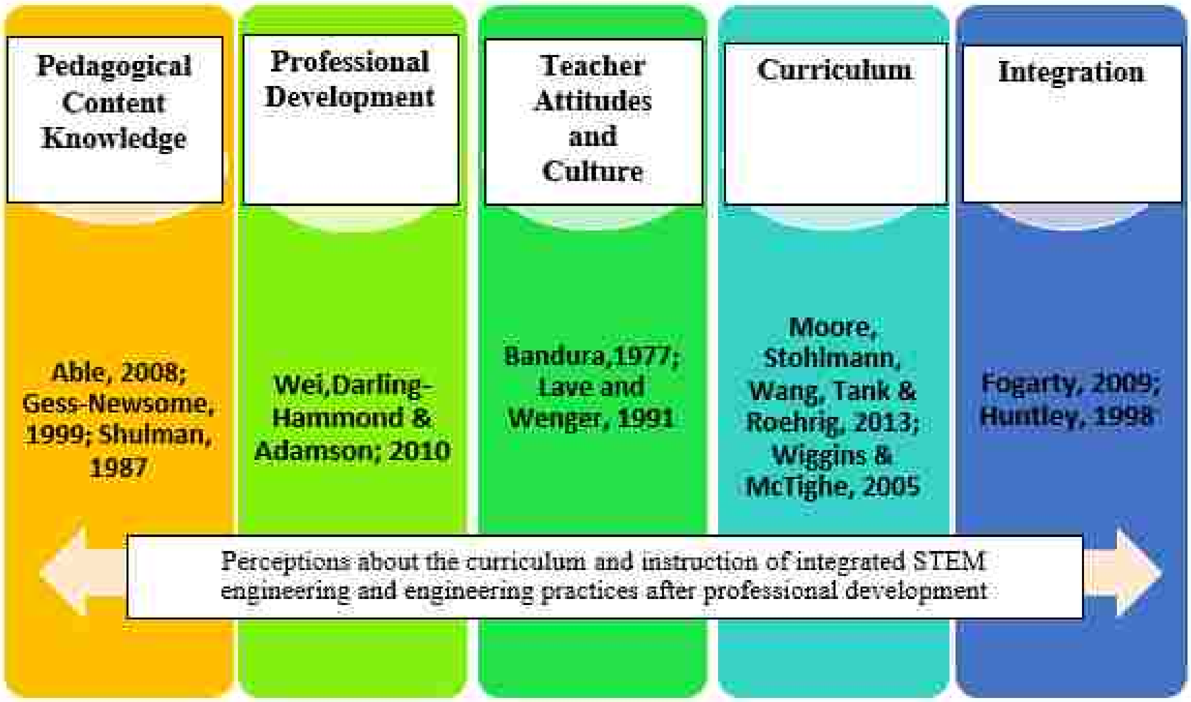


Figure 12. Key Areas of Research and Theorists Used to Support the Conceptual Framework of the Study.

During the summer and fall of 2014, 20 third through fifth grade teachers in a mid-sized school district in Northern Arkansas participated in 80 hours of integrated STEM professional development, centered on the topic of aviation, called Project Flight. The training was delivered by two University of Arkansas professors, and a graduate assistant, during two weeks in June and one day of follow-up training in October and in November of that year. The teachers were solicited from three elementary schools, Northside, Eastside, and Westside, near the local airport. The airport was the corporate partner for the professional development's Arkansas State Department of Education (ASDE) No Child Left Behind (NCLB) grant. The purpose of the professional development training was to create developmentally appropriate aviation-related STEM curriculum units using the UbD curriculum framework. The teachers for this study were drawn from this original set of participants, which resulted in a non-experimental, multi-stage convenience cluster sample of 14 teachers for this case study research on engineering and engineering practices.

The research employed a mixed method, exploratory embedded QUAL[quan] case study design (Nastasi et al., 2010), which was a predominately qualitative study that included an embedded smaller quantitative component within the larger study. The intent was to describe the complex, socially constructed realities of the Project Flight teachers, the bounded case of the research, and to ascertain the kind of meaning the teachers placed on their experiences (Hatch, 2002; Yilmaz, 2013). However, in order to understand any shifts in teacher attitudes, beliefs and sense of self-efficacy over the course of the professional development and into the spring semester of the school year, a smaller quantitative element was included in order to provide for the complementary comparison of, and evidence to, support researcher inferences (Collins et al., 2006; Gorard & Taylor, 2004; Newby, 2014).

Research Questions

One mixed methods research question, with seven subquestions, were developed to fit the framework:

Overarching Mixed Methods Research Question: Does professional development influence elementary teachers' perceptions of the curriculum and instruction of integrated STEM engineering and engineering practices in a 3-5 grade level setting?

- Subquestion 1 (QUAL): Does the impending implementation of the Next Generation Science Standards influence teachers' perceptions about STEM within their classrooms?
- Subquestion 2 (QUAL): How do engineering and engineering practices manifest within a teacher constructed elementary STEM curriculum unit?

- Subquestion 3 (QUAL): When teachers are constructing STEM curriculum units during STEM professional development, what is the role of engineering in comparison to the STEM subject domains and how is engineering integrated within the unit design?
- Subquestion 4 (QUAL): Does STEM professional development and teaching the common STEM curriculum unit change individual teachers' perceptions about how to integrate STEM domains?
- Subquestion 5 (QUAL): Does teaching the common STEM curriculum unit and STEM professional development change individual teachers' perceptions about how to integrate engineering and engineering practices?
- Subquestion 6 (QUAL): What are the perceived conduits and barriers to effective integration of engineering and engineering practices within an elementary classroom?
- Subquestion 7 (QUAN): Is there a change in teachers' self-reported efficacy to teach integrated STEM and write integrated STEM curriculum during the course of STEM professional development?

Research Overview

Study of the archival quantitative and qualitative data from the 2014 professional development training, as well as new data collected from semi-formal grade level focus group interviews in June of 2015, were analyzed separately and then merged. Top down a priori quantitative coding was used for the archived data, inductive bottom up qualitative coding for the current data. Descriptive statistics, independent *t*-tests and repeated measures ANOVA were used to analyze the quantitative data from both the archival and current data sets. Triangulation of all three elements occurred and broad findings of all three data sets were combined to form a synergistic new set of understandings that could be applied to the case of teachers in order to understand their perceptions of integrated STEM, engineering and engineering practices in an elementary setting (Onwuegbuzie et al., 2010).

Findings

Overview. Effective teacher professional development programs, according to Luft and Hewson (2014), stipulate four interrelated elements comprise effective programs—policy, teacher professional development programs, teachers and students. In the case of the Project Flight training, the policy aspect involved the state and school policies regarding state benchmark testing, school mandated programs, and policies linked to the current Arkansas K-8 Science Frameworks and upcoming NGSS science standards. The professional development element involved how the integrated STEM unit on aviation was delivered and structured by the University of Arkansas researchers as well as the training revolving around the construction of the grade level curriculum units. The 14 teachers and any changes in their understating of integrated STEM engineering and engineering practices with any subsequent shifts in praxis during the teaching of the unit with students were the remaining two aspects of effective programs and the focus of the Project Flight study.

Fundamentally, shifts in teacher perceptions of integrated STEM engineering and engineering practices seemed to be framed by teacher willingness to undergo second order change during professional development regarding their own situated praxis (Argyris, 1990). First order change involves shifts in educational processes or procedures which do not fundamentally shift teachers' belief systems concerning what it means to teach. Second order change, however, is disruptive and challenges long standing beliefs and consequently are much harder to invoke.

Engineering in elementary schools is a new domain that will likely require a shift towards constructivist, problem based, inquiry practices. Inquiry practices can conflict with the transmissive, craft knowledge of some elementary science teachers (Appleton, 2008; van Driel et al, 2014). Studying the Project Flight teachers afforded the opportunity to see how a cadre of teachers broached new content, in conjunction with new roles and responsibilities, both as individuals and as members of a horizontal learning community during the course of professional development (Allen & Penuel, 2014; Wenger-Trayner et al., 2014). The first four major findings of the study are ranked according to their significance specific to elementary engineering and professional development. Three more generalized minor findings are subsequently ranked afterwards. The major and minor findings are as follows:

- Finding 1: “The” Engineering Design Loop, a New Heuristic;
- Finding 2: Engineering as Student Social Agency and Empowerment;
- Finding 3: The Power of Supportive Learning Environments;
- Finding 4: As Goes Science Inquiry, So Goes Engineering;
- Finding 5: Curricular Integration Leans to the Known;
- Finding 6: Policy, Time Restrictions, and Accountability Pressures;
- Finding 7: Applicability and Currency Drive Use and Understanding of the NGSS.

Major Findings.

Finding 1: “The” engineering design loop, a new heuristic. Prior to the start of Project Flight, none of the teachers had undertaken any integrated engineering training. By June, all the teachers demonstrated some engineering pedagogical content knowledge (EPCK) understandings, with six teachers conceptualizing engineering as truncated stages of design of *build, modify,* and *test* denoting an overgeneralization of the function of engineering to only construction and building (Hsu et al., 2011; Lambert et al., 2007). Half of the Project Flight teachers further conceptualized engineering as the use of science within more expanded design loops. Technology and engineering, however, tended to be used as interchangeable domains within design cycles, rather than complimentary ones, wherein the distinction between engineering creating solutions to solve practical problems within the natural world and technology involving the development or modification of tools within a designed or artificial world was not clear (Katehi et al., 2009b; Rhodes & Schatble, 1989). Lessons on engineering habits of mind were not evident in the curriculum written by the teachers and they were rarely designated within the lessons the teachers highlighted. By June of 2014, 13 out of the 14 teachers viewed engineering as an algorithmic application of designated design steps very similar to elementary science teachers application of "the" scientific method (McComas et al., 2002). While there was existing research concerning engineering and STEM research literature, the development of engineering design as a heuristic was not found in the research for this finding.

Finding 2: Engineering as student social agency and empowerment. Consistent across all the teachers in the study, but most pronounced in Westside, was the perception by the teachers that engineering and design challenges allowed students who otherwise found it difficult to excel in standard school assignments, due being second language learners or because of having academic needs in other areas, to flourish. They attributed this to the differing requirements of the design challenges which accessed and highlighted these students' cognitive and dispositional strengths. Application and generalization of concepts and skills from the integrated STEM lessons into other content areas was also mentioned. Consequently, these students were able to assume leadership roles and afforded social prestige. Engineering challenges were seen as a powerful venue to form classroom communities. The literature referred to for this study does not address these core elements within this finding.

Finding 3: The power of supportive learning environments. Project Flight professional development was designed to encourage a robust social learning system through the use of horizontal grade level learning groups during training, both between the researchers and teachers and within groups of teachers when the grade levels developed curriculum units (Lave & Wenger, 1991; Wenger-Trayner et al., 2014). In each, the social context helped support active participation in shared meaning making. Learned integrated STEM content knowledge seemed to solidify during the group process of curriculum writing and shared presentation of units and discussions and was valued by the members of the groups. This finding was supported by the literature on organizational development within the research (Lave & Wenger, 1991; Wenger-Trayner et al., 2014).

However, established perceptions of science expertise among the teachers seemed to be a factor in the degree of support teachers granted each other and the students within schools. There was stark, and often negative, split between the Eastside fifth grade teachers and teachers of the two other grades which seemed to be linked to benchmark testing, teacher propagation of student misconceptions, and the presumed favoring of "fun activities" over real science inquiry by the earlier grade teachers. Some of the comments about the students were positive in terms of the students' enjoyment and motivation for STEM but some were also negative in terms of students' willingness to "think out of the box" and ask pointed questions which may have been the result of not taking into consideration both the developmental level of students for abstract thinking and some student cultural norms of maintaining harmony within a peer group and not questioning adults (Lee, 2004; Settlage & Southerland, 2007). The teachers at Westside were much more cohesive and supportive across grade levels, with empathy for the constraints placed on the various grade levels due to benchmark testing. While teachers recognized that there was less science done in the earlier grades it was attributed to time and the constraints of the current Arkansas K-8 science standards rather than teacher expertise. Conversations about the students were warm and anecdotal, and took into consideration the role having a high number of ESOL students had in understanding the science concepts and scientific language usage (Lee, 2005). Integrated STEM professional development requires positive interactions within the training itself but also seems influenced by the situated social characteristics of the classrooms where new pedagogical approaches are instituted in terms of teachers' perceptions of the effects on students and the benefits the shift in praxis affords (Barnett & Hodson; Jeanpierre, 2007).

Finding 4: As goes science inquiry, so goes engineering. Within both the Project Flight professional development and the four curriculum units, engineering manifested as a process of design with science as the core focus in both. Teachers' understanding of the function of engineering regarding the other STEM content domains seemed to be framed, by their individual understandings of, and comfort with, science inquiry pedagogical approaches. The science lessons within the curriculum units tended to be either confirmatory or highly structured in nature and retained teacher didactical control over the kinds of questions, procedures, and end results expected of the students engaged in the investigations (Schneider & Plasman, 2011; Settlage & Southerland, 2007). In numerous cases, engineering and technology were substituted for the basic or integrated process skills within the science lessons in order to help students learn the required science content rather than the science being the theoretical base for use within the other two content areas (Householder & Hailey, 2012). Teachers confounding the function and roles of engineering and technology within science, begets questions about the kinds of substantive content knowledge mental constructs and syntactical structures teachers were applying to frame the inquiry (Alake-Tuenter et al., 2013).

Minor Findings.

Finding 5: Curricular integration leaned towards the familiar. The curriculum developed by the Project Flight teachers in both the intradisciplinary and interdisciplinary forms leaned towards the known and familiar regarding integrative structures for the third and fifth grade. The fourth grade unit, however, was the most diverse with the inclusion of webbed integration within their lessons. The teachers would meet the NGSS requirements of having the majority of the content being taught integratively.

Finding 6: Policy, Time Restrictions, and Accountability Pressures. As teachers within high poverty, high ESOL elementary schools there were a number of restrictions placed upon teachers which directly and indirectly influenced how the curriculum units were developed and used in the classrooms. Under NCLB, third and fourth grade teachers were specifically charged within increasing the literacy and mathematics skills of their students. Within the three elementary schools, the effects of this federal policy was felt. New programs put into place at Northside to support students' literacy development left little remaining time to be able do the curriculum unit. School schedule for the Northside GT teacher played a part in her not continuing to use the curriculum unit with her students. District wide schedules of grade level curriculum topics influenced when the units were taught and how they were taught. At the fourth grade, but more particularly the fifth grade, curricular decisions about the integrated STEM unit construction were driven by meeting the content standards of the current science standards. The fifth grade teachers restricted how the STEM domains were used as well as the level of integration making the testing requirements the de facto arbitrator of their curriculum design choices (Brown, 1992; Porter et al., 2011).

Finding 7: Applicability and currency drive use and understanding of the NGSS. During the course of the Project Flight professional development, teachers stated an appreciation for what they perceived to be the structural difference between the NGSS standards and the current Arkansas K-8 Science Frameworks. Positive attitudes towards the perceived NGSS focus on concept development, deeper student learning, embedded integration of the CCSS, and increased potential for teacher freedom in choosing how to deliver subject matter promoted a willingness to do more STEM in the classrooms were the NGSS to be mandated.

However, the integrated STEM units the teachers constructed were to be used in the classroom that year and the NGSS had yet to be adopted. Consequently, exploration of the full integrative nature of the NGSS standards regarding STEM in classrooms was under realized because of the strategic curricular decisions in choice of standards because of teacher concerns of meeting the requirements of benchmark testing. The NGSS were always used in conjunction with the Arkansas K-8 State Science, with the NGSS being used for engineering in the third and fourth grades, and not used in a content capacity at all in fifth grade who was responsible for the terminal and only science benchmark test at the elementary level. Consequently, teachers' substantive knowledge of the NGSS (Grossman et al., 1989) seemingly did not change beyond what was learned in professional development although teacher confidence applying the NGSS built throughout the professional development and remained higher, when compared to the start of the summer professional development training, in June of 2014.

Results

In general, teachers do not undertake professional development in order to undergo fundamental changes in their existing belief systems and personal identity (Wilson & Berne, 1999). However, if teacher learning is viewed through the developmental lens of a learning progression, in that teachers develop expertise through professional development stages that are articulated, sustained, and supported by ongoing instruction then shifts in teacher understanding is possible (Schneider & Plasman, 2011). The main mixed methods research question of the study was: Does professional development influence elementary teachers' perceptions of curriculum and instruction of integrated STEM engineering and engineering practices in a 3-5 grade level setting? In short, yes. All teachers sustained higher perceptions of self-efficacy in their understanding of NGSS, integrated STEM, and writing STEM curriculum after the professional development and the teaching of the integrated STEM units. They gained understandings of engineering and engineering practices, excluding engineering habits of mind, throughout the course of the professional development and teaching of the unit as well.

Implications

The need to address two factors within teacher professional development, policy and professional development programs, are indicated by the results of this study. At a macro level, the policy requirements for sustained training at the district level to build teacher expertise in engineering and engineering practices are addressed. At the micro level, the four areas of teacher engineering pedagogical content knowledge support required to gain this expertise is framed within the six identified constants of effective teacher professional development (Fogarty, 2009; Hunzicker, 2011).

Policy. The NGSS will become Arkansas Science Standards in 2016. Unlike the former standards, which are relatively self-explanatory in terms of content, the NGSS will require sustained professional development in order for teachers to effectively transition to using them in the classroom. The NGSS are significantly different, both philosophically and structurally, from the former standards. The NGSS also requires teacher expertise in engineering and technology. For many, the learning curve will be steep. Given that teachers have already made substantive changes within their classrooms due to the CCSS, having yet another shift in standards so soon afterwards will require overt, intentional focus at the district level. Principals and districts would be recommended to find time specifically dedicated for integrated STEM, both inside and outside the classroom. School and grade level training, supported by attendant human and monetary resources, would be required to be sustained over the implementation period, so that teachers to see the transition as a fruitful and viable endeavor to undertake.

Professional Development Programs. Integrated engineering and engineering practices, within the context of the NGSS and integrative STEM professional development, will necessitate specialized and differentiated approach in order to be effective. The previously identified constants for effective development training were:

- embedded within teachers' situated practice,
- support for teachers and other stakeholders' goals,
- practicality and applicability within the teachers' educational context,
- active participation in integrative activities,
- developing a community of learners, and
- providing long-term support.

Along with these, engineering-specific professional development should be incorporated throughout (Fogarty, 2009; Hunzicker, 2011).

For professional development, schools should start small and start with the familiar. For example, provide training in constructivist inquiry pedagogical methods for use with existing science or mathematic topics taught by teachers would be a good place to begin. This makes it possible to add to the teachers' pedagogical content base and concurrently address any outstanding teacher content misconceptions. A series of small iterative group design challenges, which link back to science or math content and use the full complement of engineering design, would follow in order for teachers to gain a more concrete understanding of the process by making explicit the connections between the activities the teachers undertake and engineering syntactical and substantive structures. Additional professional development will depend on site-specific circumstances or the differentiated learning needs of the teachers. The format of the professional development could range from further whole group professional development, to co-teaching in the classroom, or individual mentoring of teachers depending on the EPCK of the teacher. Such professional development would need to address the deficiencies identified in this research, which are that teachers have a limited understanding of:

- the role and characteristics of science inquiry;
- the relationships among science, mathematics, engineering, and technology;
- the discrete differences between engineering and technological design; and
- using engineering habits of mind as an overarching dispositional framework, analogous to the Nature of Science (NOS) role's within science inquiry, to help teachers and students' sensemaking of engineering.

Future Research

Replication. Replicate and expand this study, using standardized research protocols during all phases of data collection, to other demographically similar districts within the state of Arkansas. This would provide more generalizable insights into elementary teachers understanding and application of integrated STEM engineering and engineering practices

Informal and formal support for engineering. Conduct further research into how informal communities of practice in schools support or hinder the teachers understanding and application of new engineering pedagogical practices during professional development. The results of this study also suggest that teachers in well-functioning communities of practice develop a more completed understanding of integrated STEM engineering and engineering practices within their own classroom.

Exploring the prevalence of the engineering design loop heuristic. Because of the results of this research are bound by this case, further experimental study needs to be done in order to establish a causal relationship between teachers at Stage 2 understanding of elementary engineering and the use of the design loop as a heuristic. Doing so would add to limited existing body of knowledge concerning teacher perceptions of engineering within the elementary engineering professional development research.

Engineering as social agency. Understand the ramifications of using engineering as a gateway for community building and social efficacy for disadvantaged students in an elementary classroom and how it challenges the deficit model with current science research concerning student access to science and, by extension, that of integrated STEM engineering.

Limitations of the Study

The conclusions derived from this case study, while adding to the internal validity and reliability of the research, may have limited generalizability when applied to a different population of teachers. As a case study, it also has the potential for researcher bias and subjectivity.

Some of the archival data used in this study was did not "afford a continuity of unfolding events" as the original data were not organized for research, thus requiring some reconstruction of events which could possibly result in increased researcher error, subjectivity and bias (Merriam, 2009 p. 154).

The small non-representative sample of teachers may not represent the greater population of Arkansas teachers nor teachers throughout the country. In the quantitative measures, due to the limited sample size, outliers can affect the validity of the independent *t*-tests. Having an independent rater conduct an inquiry audit of the qualitative data coding and themes would establish greater trustworthiness in the interpretation of the data.

The social dynamics and levels of acquaintance between the researcher and other participants during the interviews played a part in how and what information was shared.

Due to the timing of the focus group interviews, teachers from Northside were under-represented in the study, as were teachers from fourth grade. Follow up interviews were not undertaken at Northside. Increased teacher representation and follow up interviews could have informed and strengthened support for the broad themes within the study.

Summary

Rarely do teachers enter into professional development with the explicit purpose of challenging their fundamental belief systems and professional identity (Wilson & Berne, 1999).

However, if teacher learning is viewed through the developmental lens of a learning progression, in that teachers develop expertise through professional development stages that are articulated, sustained, and supported by ongoing instruction, then shifts in teacher understanding is possible (Schneider & Plasman, 2011). The main mixed methods research question of the study was: Does professional development influence elementary teachers' perceptions of curriculum and instruction of integrated STEM engineering and engineering practices in a 3-5 grade level setting? In short, yes. All teachers sustained higher perceptions of self-efficacy in their understanding of NGSS, integrated STEM, and writing STEM curriculum after the professional development and the teaching of the integrated STEM units. The teachers gained understandings of engineering and engineering practices, excluding engineering habits of mind, throughout the course of the professional development and teaching of the unit.

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APPENDIX A

Archived Data: Project Flight Daily Agenda

8:30 – 9:00	Introduction and Pre-Test: Jennifer, Cathy, Abbie, Bridgette. • Project Flight "Howdy Do": Jennifer. • Goals of the workshop: Jennifer
9:00 – 9:45	Introduction to STEM: Cathy
9:45 – 10:00	Break (fruit tray)
10:00 – 10:45	Nature of Science: Bridgette
10:45 – 11:30	Introduction to K-12 NGSS: Cathy
11:30 – 12:00	Qdoba Taco Bar
12:00 – 1:45	Introduction to STAGE 1: Jennifer
1:45 – 2:00	Break (Ice Cream Sandwiches)
2:00 – 3:00	Work on STAGE 1 DRAFT in grade level teams (Cathy, Bridgette, Jennifer)
3:00 – 3:30	Wrap up and Exit Card

APPENDIX B

Archived Data: Example of Project Flight Padlet

Each one of the individual documents is hyperlinked to either connected websites (NGSS Website), to Project Flight curricular PowerPoints (What is This Thing We Call the 'Nature of Science'?), downloadable documents (Stage 1 Planning) or to photographs. For all ten days of professional development, resources were uploaded to the Padlet page which served as the central warehouse for electronic information.

B1: Project Flight Padlet Page

APPENDIX C

Archived Data: Fifth Grade UbD Final Curriculum Unit

Table C 1

Fifth Grade UbD Final Curriculum Unit Stage 1

STAGE 1: DESIRED RESULTS

Science Focus Standards:

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

NGSS 7. Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

PS.6.5.4.

Compare and contrast potential energy and kinetic energy as applied to motion.

PS.6.5.5.

Classify real world examples as potential energy or kinetic energy as applied to motion.

**See also science standards about data under the math standards section.

Technological Literacy Standards:

Standard 1. Students will develop an understanding of the characteristics and scope of technology.

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

Standard 9. Students will develop an understanding of engineering design. (engineering loop)

Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Literacy Focus Standards:

Focus Standards:

RI.5.9: Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.

W.5.2: Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

SL.5.1: Engage effectively in a range of collaborative discussions (one-on-one, group, and teacher-led on grade 5 topics and texts, building on others' ideas and expressing their own ideas clearly.

Supplemental Standards:

RI.5.2: Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text.

SL.5.1(c): Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.

SL.5.1(d): Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

SL.5.4: Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

Engineering Standards:

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

Table C1 (Cont.)
Fifth Grade UbD Final Curriculum Unit Stage 1

Standard 18. Students will develop an understanding of and be able to select and use transportation technologies. **<u>Math CCSS</u>** **Math Focus Standard:** 5.MD.2 Make a line plot to display a data set of measurements in fractions of a unit (½, ¼, ⅛). Use operations on fractions for this grade to solve problems involving information presented in line plots. **Supplemental Standards:** 5.0A.2 Write simple expressions that record calculations with numbers, and interpret numerical expressions without evaluating them. Math/science: NS.1.5.3 Calculate mean, median, mode, and range from scientific data using *SI units* *NS.1.5.4* *Interpret scientific data using* ● *data tables/charts* ● *bar graphs* ● *circle graphs* ● *line graphs* ● *stem and leaf plots* ● *Venn diagrams*	3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
Transfer Goals: ***Change is constant and affects everything around you.***	
Essential Question(s): *Students will keep considering…* ● What is the value in studying/examining changes in the past, present or future? Why? Possible supplemental questions: ● How do forces affect our world? ● When should we evaluate others' work to determine its value to our own work?	**Understandings:** *Students will understand that…* Balanced and unbalanced forces affect motion of an object. Successful thinkers utilize others' ideas to enrich their own ideas. Changes in energy are caused by different forces.

Table C1 (Cont.)
Fifth Grade UbD Final Curriculum Unit Stage 1

Students will know: (knowledge)	Students will be able to: (skills)
Concepts/Terms: ○ force, motion, friction, potential energy, kinetic energy, aviation (lift and thrust), gravity, Newton's 1st Law, Newton's 2nd Law, inertia, distance, speed, velocity, mass, acceleration, Newton's 3rd Law (on opposite reactions with the wing). ● Real world examples of potential and kinetic energy ● Organization of an informative essay balanced vs unbalanced	● Synthesize information from various sources to make a conclusion ● Analyze the effects of force on motion ● Explain the difference between potential and kinetic energy ● Experiment with energy and forces ● Examine multiple examples/accounts of change (aviation, inventors, Newton's Laws/force and motion)

Table C2
Fifth Grade UbD Final Curriculum Unit Stage 2

STAGE 2: ASSESSMENT EVIDENCE	**Other Evidence:** *Students will show they have achieved Stage 1 goals by.*
Performance Tasks: *Students will show that they fully understand by evidence of.* Background for GRASPS- Specifics for each group in addition to the paragraph above: Speed: Propose a plane designed to fly the fastest Distance: Propose a plane design to fly the farthest Weight: Propose a plane design to carry the most weight. G-Your task here is to modify and design a model airplane (toy) to meet the needs of a predetermined criteria (speed, distance, velocity, weight). Then write a rationale/design brief (independently) explaining the modifications and how force and motion affected the choices you made in your design. R-Aerospace Engineer A-Hot Wheels Toy Maker Executives S-The executives want to know which airplane models will be best for different tasks they want their model airplanes to perform. P-You will use and/or modify an airplane we have already created in one of our experiments to meet the needs of your challenge.	Pre-Assessment Daily Exit Slips Lab Notebooks Observations/Anecdotal Records Peer/Self Assessment for the science content and for group work 4 Question experiment guide (in resources given) New Task: Design a model airplane

Table C3 (Cont.)

Fifth Grade UbD Final Curriculum Unit Stage 2

S- 1. Appropriate use of the words: -gravity -force -Newton's Laws -lift/thrust 2. Include notes about airplane designs from previous experiments	
Key Criteria/Rubrics: See below	

Table C4

Fifth Grade UbD Final Curriculum Unit Stage 3

STAGE 2: Learning Stages

Summary of Learning Activities:

Pre-assessment (must be done one week prior to starting the unit.)

Tell everything you know about mass, force, and motion. Also, complete the activity page below titled "Talking about forces." What is the value in studying/examining changes in the past, present or future? Why?

Optional Integration into Unit 2: Class research project on Orville & Wilbur Wright (A History of US Book 8)

	Aviation/science	Literacy (doesn't have to be everyday, but supplemental as needed)
Day 1	Galileo's Ramps activity (Newton's 1st law) (see Google Doc)	Science Journal: Galileo's Ramps Student Sheet Micro close-reads of Newton's 1st Law
Day 2	Newton's 2nd law activity (see shared Google doc "vocab and teaching of Newton's 2nd Law)	Science Journal: watch clips from videos of activities and write/summarize what is happening (2nd law lesson)

Table C3 (Cont.)

Fifth Grade UbD Final Curriculum Unit Stage 3

Day 3	Newton's 3rd Law activity page 52-53 in Stop Faking: Force and Motion	Science Journal: watch clips from videos of activities and write/summarize what is happening (2nd law lesson) https://www.youtube.com/watch?v=_sr3hBxu614 What is the action in the video. experiment/activity? Explain. What is the reaction? Explain.
Day 4	Newton's Laws Stations (use at your own discretion)	Science Journal: Reflecting on observation made in each station experiment. Close Read : Continue "History of Flight" from Model Gliders (will connect with timeline tomorrow)
Day 5	Center of Gravity experiment using pages 18-21 in "Exploring the Extreme" book	Science Journal: Recording observations from experiment Close Read: "Time Line" of aviation in Aeronautics book pages 83-86
Day 6	Delta Wing Glider Aeronautics page	Day 6
Day 7	Right Flight	
Day 8	Loop Plane possibly (rotor Motor)	
Day 9	Using the 3 designs students have learned, they will. Math - Students will have to complete line plot to match the data for their experiment. Student decides what x and y axis will be and how to record their data.	
Day 10	Business Proposal for Airplane Design	Script for proposal

Table C3 (Cont.)

Fifth Grade UbD Final Curriculum Unit Stage 3

Student success at transfer, meaning, and acquisition depends upon.

Possible Cross-Curricular Connections:

-Study aviation and inventions in unison with unit two during reading activities (During unit 2, use major innovator in aviation to model research during writers workshop).

-Examine the changes in aviation and why those changes were made (use texts on this topic to incorporate into unit 2 and main idea).

-Tie in with Renaissance/Leonardo da Vinci's flying contraptions.

1. **Galileo's Ramp (Force & Motion- Stop Faking it! pgs. 4-6)**
2. **Loop Plane Activity- Zinger #33 (Directions found in Project Flight binder under day 3 or http://www.abc.net.au/science/surfingscientist/pdf/lesson_plan06.pdf)**
3. **The Basics of Force and Motion two page article (http://www.lakeshorelearning.com/media/product_guides/DD354.pdf)**
4. **NASA Gravity Games**
5. **Right Flight activity- pgs. 52-57- Aeronautics: An Educator's Guide with Activities in Science, Mathematics, and Technology Education (located in Project FLIGHT binder)**
6. **Chapter One Newton's First Law-www.scilinks.org, Code SFF01 - "Newton's First Law" / good activities OR Force Code SFF02 " How Thing Fly".**
7. **Flight Activities-pgs. 40-76 Aeronautics: An Educator's Guide with Activities in Science, Mathematics, and Technology Education (located in Project FLIGHT binder)**
8. **Newton's Three Laws-http://www.youtube.com/watch?v=mn34mnnDnKU&safe=active**
9. **https://howthingsfly.si.edu/activities simulation-like activities!!!!!!!!!**

PADLET PAGE LINK-http://padlet.com/xxx

SCOPE AND SEQUENCE OF UNIT

Day of the Week	Week One	Week Two
Monday	**Pre-assessment Aviation Overview Introduce Essential Questions**	**Flight Timeline- pgs. 84-85 Wright Brothers (glider activity)**
Tuesday	**Potential/Kinetic Activities Force/Motion/Galileo's Ramp (flipchart-found on google drive) Exit Slip One- Page 7**	**1st Airplane Design Challenge- NASA Aeronautical Book (pgs. 52-59). Focus conversations around what forces are happening on the plane and how that it is affected when changes are made. Exit Slip Four-Page 10**

Table C3 (Cont.)
Fifth Grade UbD Final Curriculum Unit Stage 3

Wednesday	**Introduction to velocity/acceleration/speed/distance/lift/thrust (flipchart-found on google drive)** ***Loop Plane Experiment- Students will respond in their science notebook by completing the loop experiment using the Engineering Design Loop** **Focus conversations around what forces are happening on the plane and how that it is affected when changes are made.** **Exit Slip Two-Page 8**	**2nd Airplane Design Challenge- NASA Aeronautical Book (pgs. 60-68)** **Focus conversations around what forces are happening on the plane and how that it is affected when changes are made.** **Compare/contrast to previous experiments.** **Exit Slip Questions:** **1) Think back on the various designs you have used in creating an airplane. Write about two improvements you made after realizing your plane wasn't as effective as possible. What was the change? What made you choose to do that?**
Thursday	**Introduce Newton's Laws.** **Hands On Station Rotation where students can show understanding of all three** **Exit Slip Three- Page 9**	**Review/Catch UP/Add another activity found on map.**
Friday	**NASA Rollercoaster Activity.** ***Students will write up experiment in science notebook**	**Performance Assessment/Article Assessment (use article and require students to answer TDQ's)**

EXIT SLIP RUBRIC: also checkout http://rubistar.4teachers.org/

APPENDIX D

Archived Data: Eastside Third Grade End Assessment

As part of the November training, each group presented a shortened version of their final UbD curriculum unit. The following picture comes from the grade level PowerPoint, Slide 5, engineering performance task which Eastside developed along with the formative assessments the teachers planned to use.

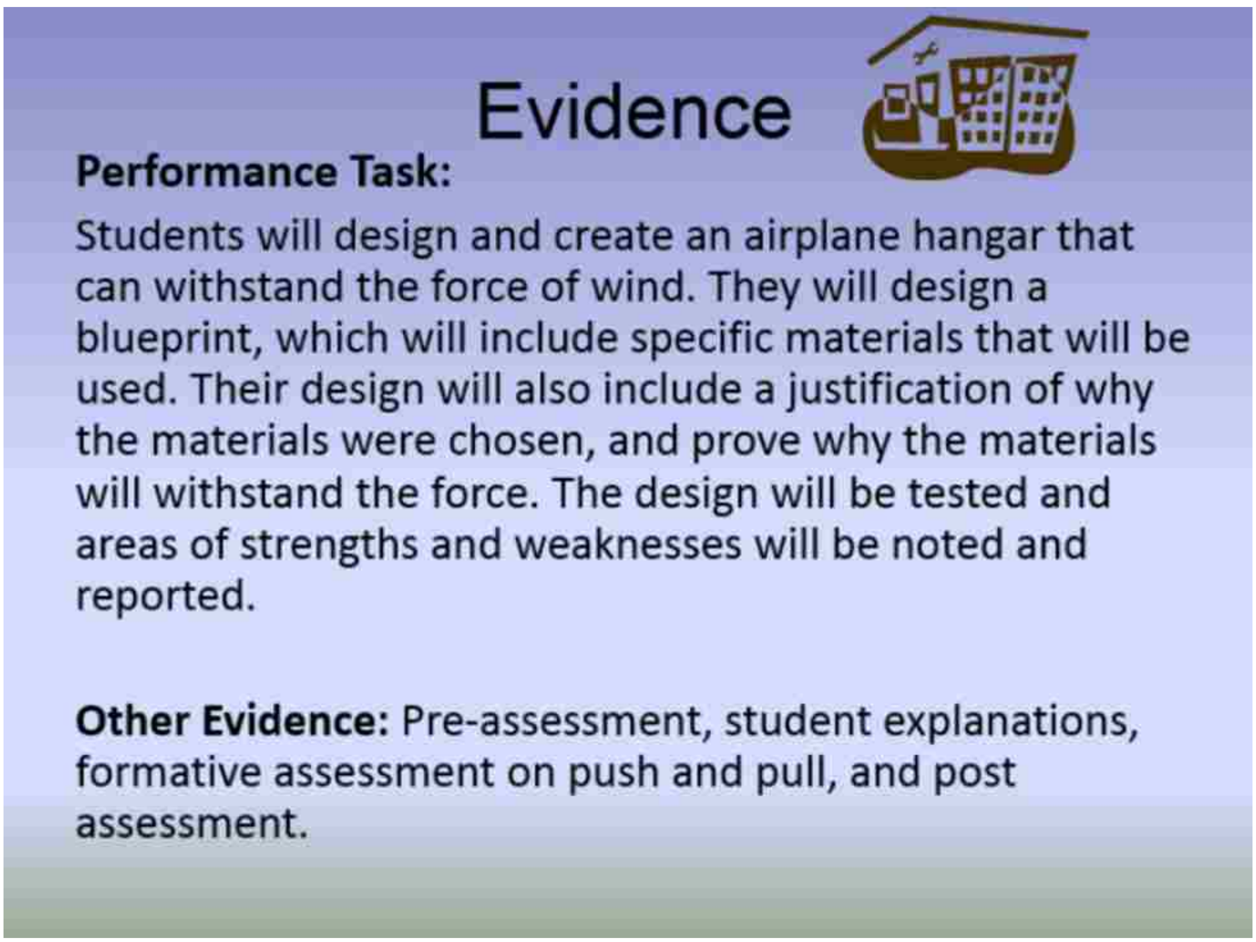

Figure D1: Eastside Third Grade End Assessment

APPENDIX E

Archived Data: Example from Fourth Grade STEM Weather Lesson Plan

This is an copy of one of the pages weather stations to which the fourth grade students were assigned. Citations have been added.

Wind Sock

Note: Picture licensed for non-commercial reuse.

"A wind sock is a type of kite used to detect wind direction. It is a tapered tube of cloth that is held open at one end by a stiff ring. Wind is directed down the tube, causing the narrow end to point in the same direction the wind is blowing. Brightly colored wind socks are used at airports to help pilots determine the wind direction along the ground. Meteorologists use wind direction to help predict weather." (NASA (n.d.). Wind in Your Socks. Retrieved from https://www.nasa.gov/ pdf/205715main_Wind_in_Your_Socks.pdf

How to make a wind sock: See pages 29-38 in the booklet Aeronautics: An Educator's Guide or see the following website:

http://www.weatherwizkids.com/experiments-windsock.htm.

APPENDIX F

Archived Data: Example of Exit Card

In your work today, how confident do you feel about applying NGSS in your classroom? Please circle the number as to your answer.

Not confident	Somewhat confident	Confident	Very confident	Extremely Confident
1	2	3	4	5

What did you learn/do today during the workshop that led to your score?

APPENDIX G

Archived Data: Project Flight Pre Post Test

1. How do you know that your students understand a concept?

2. How is a STEM lesson different from a traditional science lesson?

3. Give an example of how you might use Common Core ELA/Literacy standards in a science lesson.

4. What is the greatest area of concern when addressing the needs of students with Limited English Proficiency (LEP) in the science classroom?

5. How can we differentiate science lessons for students with Limited English Proficiency?

6. Give an example of an enduring understanding (big idea) in science.

7. What resources can you list that help you when creating science units?

8. What is the engineering design loop?

9. On a scale from 1-5 (with 1 being least familiar), how familiar are you with Next Generation Science Standards?

10. On a scale from 1-5 (with 1 being least familiar), how familiar are you with implementing STEM (Science, Technology, Engineering, and Mathematics) in the classroom?

APPENDIX H

Archived Data: First Ten Questions of the STEM-TEBI

Directions: Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.
SA= strongly agree **A**=agree UN=uncertain **D**=disagree **SD**=strongly agree

1.	When a student does better than usual in integrated STEM, it is often because the teacher exerted a little extra effort.	SA A UN D SD
2.	I will continually find better ways to teach integrated STEM.	SA A UN D SD
3.	Even if I try very hard, I will not teach integrated STEM as well. as I will most subjects.	SA A UN D SD
4.	When the integrated STEM grades of students improve, it is often. due to their teacher having found a more effective teaching approach.	SA A UN D SD
5.	I know the steps necessary to teach integrated STEM effectively.	SA A UN D SD
6.	I will not be very effective in monitoring integrated STEM projects.	SA A UN D SD
7.	If students are underachieving in integrated STEM, it is most likely. due to ineffective integrated STEM teaching.	SA A UN D SD
8.	I will generally teach integrated STEM ineffectively.	SA A UN D SD
9.	The inadequacy of a student's STEM background can be overcome by good teaching.	SA A UN D SD
10.	The low STEM achievement of some students cannot generally be blamed on their teachers.	SA A UN D SD

APPENDIX I

Archived Data: Professional Development Schedule

The professional development educative curriculum, over the course of the two-week summer training and subsequent two days of fall Saturday sessions, was comprised of five major elements: (1) direct instruction on STEM content and teaching pedagogy or UbD elements; (2) hands-on STEM investigations or design challenges; (3) expert presentations or field trips; (4) cooperative team work developing the Project FLIGHT UbD curriculum units; and (5) group presentations of lessons or units. The table below indicates the curricular sequence of these elements and, within parenthesis, the minutes spent on each and integration type.

Table I

Professional Development Schedule

Day 1: June 9	Intro to STEM (45) Intradisciplinary Cellular	Nature of Science (45) Intradisciplinary Cellular	K-12 NGSS (45) Intradisciplinary Cellular	UbD-Stage 1 (45) Intradisciplinary Cellular	Unit Plan (60) Integrated Webbed
Day 2: June 10	Balloon Hoover Craft. (135) Integrated Webbed			UbD-Stage 2 (45) Integrated Webbed	Unit Plan (60) Integrated Webbed
Day 3: June 11	Loop Planes (30) Intradisciplinary Cellular	Expert: Civil Engineering-Airports (130) Integrated Webbed	STEM Classroom (15) Integrated Webbed	UbD-Stage 3 (45) Integrated Webbed	Unit Plan (60) Integrated Webbed
Day 4: June 12	UbD Peer Review Stage 1 and 2 (45) Integrated Webbed	Needs of the LEP in Science (45) Intradisciplinary Sequenced	Windsock (135) Intradisciplinary Sequenced		Unit Plan (45) Integrated Webbed
Day 5: June 16	Field Trip to Local Airport (315) Integrated Webbed	Field Trip Debrief (40) Integrated Webbed			Unit Plan Revision (20) Intradisciplinary Connected

Table I (Cont.)
Professional Development Schedule

Day 6: June 17	Expert: Geoscience (70) Interdisciplinary Sequenced	4 Question Strategy (120) Interdisciplinary Shared		Presentation Rubric (15) Intradisciplinary Cellular	Development of Presentation (60) Intradisciplinary Cellular
Day 7: June 18	Rigor in STEM and NGSS (45) Intradisciplinary Cellular	Balsa Wood Planes (120) Intradisciplinary Cellular	Differentiation in the STEM Classroom. (45) Intradisciplinary Connected		Development of Unit Draft Presentation (45) Intradisciplinary Nested
Day 8: June 20	Expert: ROTC Aviation. (60) Integrated Webbed	Misconceptions in Science (30) Intradisciplinary Connected	Misconception in Content-Frayer Charts (60) Interdisciplinary Sequenced		Development of Unit Draft Presentation (45) Integrated Webbed UbD Unit Presentations (60) Integrated Webbed
Fall 1: October 11	5th Grade Teaching Share (20) Interdisciplinary Sequenced	Science Task Analysis (60) Intradisciplinary Connected Science Cooperative Roles. (15) Intradisciplinary Cellular	Parachute Design. (120) Interdisciplinary Shared		UbD Team Curriculum Revision. (45) Intradisciplinary Connected
Fall 2: November 8				Designing Complex Instruction (60) Interdisciplinary Shared	Final Unit Presentation (195) Interdisciplinary Sequenced

Note: Light blue indicates direct instruction on STEM, dark blue indicates a STEM investigation/challenge, tangerine indicates experts or field trip, green indicates STEM pedagogy, light yellow direct instruction on UbD, and dark yellow indicates cooperative team work.

APPENDIX J

Current Data: Interview Protocol

Table J
Interview Protocol

Introduction (2 minutes)	Thank you so much for agreeing to meet with me to talk about your Project Flight units today. I am contacting the teachers, in grade level groups, in order to solicit feedback about the implementation of your common units in the classroom and see what your perceptions towards STEM, Understanding by Design, the Next Generation Science Standards, and Engineering are now that how have had time to reflect on the process over the course of a year. The information you provide during this focus group with serve two functions. It will be used as data collection for the Project Flight study conducted in the fall. It also will serve as data for my doctoral thesis which deals with STEM professional development.
Ground Rules (2 minutes)	Feel free to treat this as a discussion and respond to what others are saying, whether you agree or disagree. I'm interested in your opinions and whatever you have to say is fine with me. There are no right or wrong answers. I am just asking for your opinions based on your own personal experience and to learn from you. Don't worry about having a different opinion than someone else. But please do respect each other's answers or opinions. If there is a particular question you don't want to answer, you don't have to. I will treat your answers as confidential. We are only going to use first names during the discussion. Pseudonyms will be substituted afterwards and I will not include information that could identify you in any study that is published. Along that line, please respect the privacy of everyone in the room and not share or repeat what is said here.

Table J (Cont.)
Interview Protocol

Ground Rules (2 minutes)	Before we begin, I would like to review a few ground rules concerning the discussion. Along that line, please respect the privacy of everyone in the room and not share or repeat what is said here. During this interview, we will be doing three kinds of activities. We will be verbally discussing the unit, intermixed with short Think-Write-Pair-Shares and a Post-It-Note activity involving your common grade level unit outline and two lessons. I will be tape recording the discussion today and also taking notes because I don't want to miss any of your comments and collecting the papers. Is everyone OK with this session being tape recorded and collecting the papers? [GET VERBAL CONSENT] This discussion is going to take approximately 60 minutes to do. I ask that you stay for the entire time. Does anyone have any questions before we start?
Introduction (2 minutes)	[START TAPE RECORDER NOW] Today's date is _____2015. We are at ___________________Elementary and the time is ____. I have received permission from the group to record our discussion today. I am Bridgette and I will be facilitating the meeting. First of all, introductions. Starting to my left, please say your first name, how many years you have been teaching, and how many years at this grade level. I have brought along a folder for each of you just to make things a bit more efficient. Please take out the blank pieces of paper and the pen and we will get started as soon as you are ready. Pass out and interview folder to each of the participants. Included in the folder are the following: numbered index cards, 3 yellow 3 x 5 Post-it-Notes and 3 orange 3 x 5 Post-it-Notes, a yellow highlighter, a blue pen, the grade level common UbD templates along with the multi-discipline STEM lesson and the Engineering specific lessons (all of which are turned backwards) with an instruction slip paper clipped to them.

Table J (Cont.)
Interview Protocol

(5 minutes)	*Warm Up*: So that I can get a mental snapshot, can you describe what STEM looked like in your classroom throughout the year? Prompt: Can you tell me more about your students in general? Prompt: What was their attitudes and approach to the STEM lessons? Prompt: Could you teach STEM the way you wanted?
Perceptions of NGSS Qual 1,6 (Up to 10 minutes) Think-Write-Shares will be recorded on the numbered index cards and will serve as points of discussion.	1. What kind of role do the science standards play in how you structure your curriculum? [Individually, Think-Write-Share] ***2***. *The Next Generation Science Standards are now being considered in the state legislature. How do you think the NGSS standards compare to the current Arkansas Science Frameworks?* [Individually, Think-Write-Share**].** 3. *If you had to use the NGSS standards next year, would that change how you would approach STEM your classroom?* Prompt: What do you know about how the NGSS is structured? (cross cutting concepts, assessment boundaries, inclusion of science and engineering practices). Prompt: What role do you think engineering plays within NGSS? Prompt: What is would be your comfort level in terms implementing the standards? Prompt: What would have to happen for you to feel successful in using the standards in your classroom?
Prof Dev UbD Qual 2, 3, 4, 6 (Up to 10 minutes)	4. Thinking back over the Project Flight training you received last summer and in the fall, what do you perceive were the main objectives of the training? 5. How did the professional development you received influence your perceptions of STEM? Prompt: What elements, for you personally, were you able to actively apply in your own classroom? Why? Prompt: Which elements, for you personally, were not as applicable? Why? 6. What are your perceptions about the effectiveness of using the Understanding by Design (UbD) model to write curriculum? Prompt: Prior to this training, had you developed any curriculum yourself?

Table J (Cont.)
Interview Protocol

	Prompt: Prior to this training, had you developed any curriculum using the model? Prompt: Did your experiences with the UbD prior to the training influence how the unit was created? [Individually, Think-Write-Share] ***7.*** *Part of professional development is looking for an effective fit between teacher needs and provided training. If we could go back in time, knowing what you know now, what could be done to provide a best fit for you personally?*
Integrated STEM and Engineering Qual 2, 3, 4 (Up to 10 minutes).	[Individually, Think-Write-Share] ***8.*** *What is your working definition of what it means to integrate curriculum?* 9. To your mind, what defines and characterizes engineering and engineering practices within a classroom? 10. What is the role engineering plays in relationship to the other STEM subjects? Prompt: How do you know it is engineering rather than another subject? Prompt: What stands out as making each content area different? The same? 11. Is there a difference in approach if you have to teach STEM in an integrative way? Prompt: Is there a proportion that has to be taught to make it integrated or how would you mesh the different content areas? [Individually, Think-Write-Share**]** ***12.*** *What was your groups approach to integration when you all were designing your common curriculum unit?* Probe: What were some of the important considerations you made?

Table J (Cont.)
Interview Protocol

Engineering in Curriculum Qual 2, 4 (15 minutes)	Protocol for Engineering and Engineering Practices Within the UbD Unit. In this part of the interview, you will be looking at part of your UbD template, your own lesson, and a STEM lesson from the University. What I would like you to do is spend about 15 minutes looking over the papers, highlighting key parts, and making comments on the paper based on the directions listed on the slip inside the folders. Directions: • Individually, please look over the three documents and do the following. • Highlight what you would consider to be engineering practices within each of the lessons. • Put a key word or phrase next to where you highlighted indicating what the practice was. (If you want to make a key at the top and just use a short hand that would be fine.) • Using the yellow Post-It note, describe how you determined what engineering *was present* in each of the STEM document and stick it to the paper. • Using an orange Post-It-Note, describe how you perceive engineering was *integrated* within STEM documents. • Please put your papers back in the folder facing backwards. • If you finish before the others, just give them a quiet moment to finish up and then the group will get started again.
Teaching Integrated Stem Perceptions Teaching Engineering Qual 1, 3, 4, 5, 6. (Up to 15 minutes)	13. When did your grade level teach the unit and over what period of time? 14. How did you, as a grade level, decide to implement the common unit at the grade level? 15. Once you applied it in your own classroom, what happened? Prompt: How did you deal with the Essential Questions, Enduring Understandings, and Core Skills? Prompt: Was any one of these more important than the other? Why or why not? 16. Did teaching the unit change how you viewed integrating STEM and engineering within your classroom? Prompt: What stood out to you in terms of things that worked or did not work for you and your class? Prompt: Were there any barriers or conduits in terms of teaching the unit?

Table J (Cont.)
Interview Protocol

Final Thoughts (5 minutes)	[Individually, Think-Write-Share] ***17****. Now that you have taught the unit, let's imagine that the Next Generation Science Standards have become the Arkansas standards. You have come back to redesign the Project Flight curriculum unit to reflect what you now know about integrating engineering and engineering practices. What would be your approach towards integration this time around? What kind of specific professional development would help with doing so?* [Handout of NGSS Science and Engineering Practices]. Prompt: In terms of integration of the subject domains? Prompt: In terms of integrating the practices? 18. Is there anything else that you think is important to include in the discussion or would like to share? If you have any other questions, please do feel free write them down on the Think-Write-Share card along with the pseudonym that you would like me to use for you. Then put everything back in the folder for collection. Thank you so much for spending the time doing this. I do appreciate all your help greatly. STOP RECORDING. Collect papers

APPENDIX K

Example of Engineering Habits of Mind Coding for a STEM Lesson

The Marshmallow Shooter was designated by the third grade teachers at Westside as their best STEM lesson. Listed below is an excerpt of the coding used to determine the engineering and engineering habits of mind in the lesson using a combination of the engineering design loop steps of the Massachusetts Department of Education (2006) *Science and Technology/Engineering Curriculum Framework* and the Committee on K-12 Engineering Education (2009) precepts for K-12 Engineering which includes systems thinking; a combination of science, technology and mathematics; along with the engineering habits of mind which involves systems thinking, creativity, optimism, collaboration, communication, and ethical considerations.

Table K
Engineering Habits of Mind Coding

MDE Engineering Design Loop Steps		***Committee on K-12 Engineering Education***	
Element	*Comment*	*Element*	*Comment*
Identify the need or problem	*No*	*Systems of Design*	*No*
Research the need or problem	*No*	*Science*	*Students were introduced to the definition of a push and the idea of force moving an object at the start of the lesson. Students were asked to predict and observe what a marshmallow would do when shot.*
Develop possible solution (s).	*No*	*Technology*	*Constructed shooter out of a cup and balloon.*
Select the best possible solution.	*No*	*Mathematics*	*Did measurement of distance (unclear if used rulers/yardsticks sticks)*
Construct a prototype.	*Not a prototype but did construct a technology.*	*Systems Thinking*	*They made a simple system.*

Table K (Cont.)
Engineering Habits of Mind Coding

MDE Engineering Design Loop Steps		Committee on K-12 Engineering Education	
Element	Comment	Element	Comment
Test and evaluate the solutions.	No. The students were asked to infer a change according to the handout and recorded observations.	Creativity	Replicative. Followed the directions but changed the object being shot.
Communicate the solutions	Student recorded what they observed but did not use specific science language or link it to the forces according to the handout.	Optimism	No evidence in order to make a decision within the handout.
Redesign	No	Collaboration	Individual although pictures indicate whole grade level shot off the shooters as a mass.
Type of Concept Integration	This was a silo lesson that was activity based. While there was some measurement to give evidence for distance, the focus, in terms of science was on observation of a phenomena and to arouse curiosity.	Communication	Filled a worksheet. Unclear the content of of the debrief from the intial activity handout.
Overall comments	There is a misconception in the notes. " A little force won't move an object very far, but a big force will." Simplified for second and third grade. Did not take into account the mass of an object changes the amount of force needed to move it. Problematic in terms of teacher as conduit for misconceptions.	Ethical Considerations	There were no harmful aspects to the activity.

APPENDIX L

IRB Approval Letter

UNIVERSITY OF ARKANSAS

Office of Research Compliance
Institutional Review Board

May 21, 2015

MEMORANDUM

TO:	Jennifer Beasley Cathy Wissehr Bridgette Fincher
FROM:	Ro Windwalker IRB Coordinator
RE:	PROJECT MODIFICATION
IRB Protocol #:	14-06-787
Protocol Title:	*Project SOAR: Building Efficacy and Practice in Writing and Teaching STEM Integrated Units*
Review Type:	☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 05/20/2015 Expiration Date: 07/01/2015

Your request to modify the referenced protocol has been approved by the IRB. **This protocol is currently approved for 35 total participants**. If you wish to make any further modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

Please note that this approval does not extend the Approved Project Period. Should you wish to extend your project beyond the current expiration date, you must submit a request for continuation using the UAF IRB form "Continuing Review for IRB Approved Projects." The request should be sent to the IRB Coordinator, 109 MLKG Building.

For protocols requiring FULL IRB review, please submit your request at least one month prior to the current expiration date. (High-risk protocols may require even more time for approval.) For protocols requiring an EXPEDITED or EXEMPT review, submit your request at least two weeks prior to the current expiration date. Failure to obtain approval for a continuation *on or prior to* the currently approved expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu.

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