Factors affecting in-service teacher engineering design instruction as a portal for developing science conceptual understanding

by

Mohammed Abdullah Aljohani

B.S., University of Tabuk, 2009
M.S., University of Colorado, Colorado Springs, 2014

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Curriculum and Instruction
College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2019

Abstract

This mixed-methods study investigated the factors that influence in-service teacher integration of science content and student science conceptual understanding during engineering design instruction. Open-ended questions, classroom observations, and documents analysis were conducted to qualitatively explore the factors impacting science content integration and science conceptual understanding. A cross-sectional survey was conducted to investigate the effect of elementary teacher preparation, self-efficacy for, and beliefs about teaching engineering design on the integration of science content and science conceptual understanding. The research study included a sample of 222 participants who were elementary in-service teachers in the State of Kansas.

The significant findings of a Multivariate Analysis of Variance (MANOVA) revealed two factors, which positively influence science content integration and students' conceptual understanding during engineering design instruction: (a) professional development workshops in teaching engineering design, and (b) experience teaching engineering design. Also, this statistical test indicates undergraduate and graduate academic preparation did not influence science content integration and students' science conceptual understanding during engineering design instruction. A correlational analysis of the data found that teachers' self-efficacy of teaching engineering design is statistically correlated to science content integration and students' science conceptual understanding, while teachers' beliefs about teaching engineering design is not correlated.

A triangulation of the qualitative data analysis presented the dynamic dimension of school priority as a mitigating factor in framing engineering design instruction in K-6 classrooms. The findings of the study illuminate the remarkable variation in elementary teacher professional development to deliver engineering design instruction across Kansas districts, which impacts student progression in sophistication in science reasoning of disciplinary core ideas within an engineering design instructional context. This dimension explains the diminished inclusion of science content during engineering design instruction. The availability and degree of Next Generation Science Standards (NGSS) aligned curricula, professional development, allocated time to teach engineering design compromise the potential for engineering design instruction to develop science conceptual understanding. Elementary teachers reported the need to experience engineering design the elementary science methods course. Future research into the role of the elementary science methods course should be explored as a viable portal for preparing teachers to integrate science content during engineering design instruction as mandated in the NGSS for K-6 classrooms.

Factors affecting in-service teacher engineering design instruction as a portal for developing science conceptual understanding

by

Mohammed A Aljohani

B.S., University of Tabuk, 2009
M.S., University of Colorado, Colorado Springs, 2014

A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Curriculum and Instruction
College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2019

Approved by:

Major Professor
Kimberly A. Staples, Ph.D.

Copyright

Abstract

This mixed-methods study investigated the factors that influence in-service teacher integration of science content and student science conceptual understanding during engineering design instruction. Open-ended questions, classroom observations, and documents analysis were conducted to qualitatively explore the factors impacting science content integration and science conceptual understanding. A cross-sectional survey was conducted to investigate the effect of elementary teacher preparation, self-efficacy for, and beliefs about teaching engineering design on the integration of science content and science conceptual understanding. The research study included a sample of 222 participants who were elementary in-service teachers in the State of Kansas.

The significant findings of a Multivariate Analysis of Variance (MANOVA) revealed two factors, which positively influence science content integration and students' conceptual understanding during engineering design instruction: (a) professional development workshops in teaching engineering design, and (b) experience teaching engineering design. Also, this statistical test indicates undergraduate and graduate academic preparation did not influence science content integration and students' science conceptual understanding during engineering design instruction. A correlational analysis of the data found that teachers' self-efficacy of teaching engineering design is statistically correlated to science content integration and students' science conceptual understanding, while teachers' beliefs about teaching engineering design is not correlated.

A triangulation of the qualitative data analysis presented the dynamic dimension of school priority as a mitigating factor in framing engineering design instruction in K-6 classrooms. The findings of the study illuminate the remarkable variation in elementary teacher professional development to deliver engineering design instruction across Kansas districts, which impacts student progression in sophistication in science reasoning of disciplinary core ideas within an engineering design instructional context. This dimension explains the diminished inclusion of science content during engineering design instruction. The availability and degree of Next Generation Science Standards (NGSS) aligned curricula, professional development, allocated time to teach engineering design compromise the potential for engineering design instruction to develop science conceptual understanding. Elementary teachers reported the need to experience engineering design the elementary science methods course. Future research into the role of the elementary science methods course should be explored as a viable portal for preparing teachers to integrate science content during engineering design instruction as mandated in the NGSS for K-6 classrooms.

Table of Contents

List of Figures ... xiv

List of Tables ... xv

Chapter 1 - Introduction ... 1

  Background of the Problem ... 1

  Statement of the Problem ... 3

  The Purpose Statement ... 5

  The Significance of the Study ... 6

  Research Questions ... 6

  Research Design ... 7

  Theoretical Framework ... 9

  Limitations ... 11

  Delimitations ... 11

  Terms and Definitions ... 12

  Summary ... 12

Chapter 2 - Literature Review ... 14

  Self-Efficacy, Belief, and Perception ... 15

    Beliefs About Teaching Engineering Design ... 15

    Self-Efficacy for Teaching Engineering Design ... 17

    Perceived Barriers ... 18

  The Framework for K-12 Science Education ... 20

    Dimension 1: Practices ... 21

    Dimension 2: Crosscutting Concepts ... 23

    Dimension 3: Disciplinary Core Ideas ... 24

  Pedagogical Content Knowledge ... 25

  Science Teacher Preparation ... 27

    Academic Preparation ... 27

    Professional Development ... 29

    Teacher Experience ... 32

  Engineering Design and Student Achievement ... 34

  Summary 39

Chapter 3 - Research Methods 40
  Introduction 40
    Mixed Methods Validity 41
  Research Questions 43
  Qualitative Phase 43
    Data Sources 44
      Open-ended questions. 45
      Observation. 45
        Electronic Quality of Inquiry Protocol (EQuIP). 46
        Field notes 46
      Document analysis. 47
        Educators Evaluating the Quality of Instructional Products (EQuIP). 47
    Validity and Reliability 50
    Procedures 51
    Qualitative Data Analysis 51
      Preparing and organizing the data. 51
      Coding procedure. 52
      Themes. 53
  Quantitative Phase 54
    Participants 54
    Measurements 55
      Demographic data. 55
      Teachers' preparation. 56
        Teachers' academic preparation. 56
        Degree level. 57
        Professional development. 57
        Years of teaching engineering design. 57
      Self-efficacy for teaching engineering design 59
      Beliefs about teaching engineering design. 60
      Science content integration. 60

Students’ science conceptual understanding. 61
Quantitative Data Analysis 61
Variable descriptions. 62
Measurement reliability. 62
Factor analysis. 62
Independent t-test 63
One Way Analysis of Variance (ANOVA). 63
MANOVA 63
Correlation 63
Mixed Methods Analysis 64
Summary 65
Chapter 4 - Findings 66
Qualitative Data Analysis 66
Research Question One 66
Analysis of Open-Ended Questions 66
Teaching experience (D1) 67
Level of EDI implementation 68
Obstacles for pre-implementation and novice experience. 71
Academic preparation (D2). 73
The importance of engineering design integrated into science methods courses. 74
Professional development (D3) 77
The influence of professional development. 77
Not offered professional development. 80
Belief about teaching engineering design (D4). 81
Perceptions toward engineering design. 81
Barriers and difficulties. 82
Self-efficacy of teaching engineering design (D5) 84
Levels of self-efficacy. 85
Factors that impact teacher preparedness and confidence 86
Engineering design and science content integration (D6) 88
Level of integration. 88

    Factors that influence science and engineering integration. 90
  Engineering design and students' science conceptual understanding (D7) 91
    Positive influence 92
    Issues limiting students' science conceptual understanding. 92
Analysis of Classroom Observations. 94
  First classroom observation 94
    Instructional factors. 94
    Discourse factors. 95
    Assessment factors. 95
    Curriculum factors. 95
  Second classroom observation. 95
    Instructional factors. 96
    Discourse factors. 96
    Assessment factors. 96
    Curriculum factors 96
  Third classroom observation 97
    Instructional factor. 97
    Discourse factors. 97
    Assessment factors. 97
    Curriculum factors. 98
  Fourth classroom observation 98
    Instructional factors. 98
    Discourse factors. 98
    Assessment factors. 98
    Curriculum factors. 99
Analysis of Lesson Plans 99
  Lesson plan one: 99
    NGSS instructional supports. 100
    Monitoring NGSS student progress. 100
  Lesson plan two: 100
    NGSS instructional supports 101

Monitoring NGSS student progress. 101
Lesson plan three 101
NGSS instructional supports. 102
Monitoring NGSS student progress. 102
Lesson plan four: 103
NGSS instructional supports 103
Monitoring NGSS student progress. 104
Qualitative Summary 104
Quantitative Data Analysis 106
Participant Demographics 106
Validity Check 109
Reliability of Measuring Scales 110
Barriers to Teaching Engineering Design 111
Statistical Analysis of the Demographical Data 111
Gender 112
Title I eligible school 112
Ethnicity 112
Research Questions Two and Three 113
Academic preparation. 113
Degree level. 114
Professional development 115
Engineering design teaching experience 118
Research Question Four 121
Research Question Five 122
Mixed-Methods Analysis 122
Research Question Six 122
Convergence. 125
Divergence 126
Summary 126
Chapter 5 - Discussion and Implications 127
Overview of the Problem 127

Summary of Findings 128
  Teachers’ Experience 129
  Academic preparation 131
  Professional Development 132
  Self-Efficacy of Teaching Engineering Design 133
  Beliefs About Teaching Engineering Design 134
Implications 136
  Implications for Implementing Engineering Design in Saudi Arabia 138
Limitations and Future Research 139
References 141
Appendix A - The Survey 153
Appendix B - EQuIP Rubric for Lessons & Units 163
Appendix C - Electronic Quality of Inquiry Protocol 174
Appendix D - The IRB Approval 187

List of Figures

Figure 1.1. The theoretical framework for the factors affecting the integration of science content during EDI and students' science conceptual understanding. 9

Figure 3.1. Flowchart showing the procedures for this convergent parallel mixed methods design. Adapted from "Designing and Conducting Mixed Methods Research" (p. 70 & 76), by J. W. Creswell and V. L. Plano Clark, 2017, Thousand Oaks, CA: Sage Publications... 41

Figure 3.2. The demographic locations of the participants. 55

Figure 4.1. Level of EDI implementation. 68

Figure 4.2. The concept map presents the summary of the qualitative data results for the domains of the open ended questions. 105

Figure 4.3. Participants' responses to items as barriers to integrating engineering design. 111

List of Tables

Table 3.1 44
Table 3.2 58
Table 4.1 67
Table 4.2 107
Table 4.3 109
Table 4.4 110
Table 4.5 110
Table 4.6 112
Table 4.7. 113
Table 4.8. 114
Table 4.9. 115
Table 4.10. 115
Table 4.11. 116
Table 4.12 117
Table 4.13. 118
Table 4.14 119
Table 4.15 120
Table 4.16. 121
Table 4.17 123

Chapter 1 - Introduction

In 2013, a major shift in science education changed the way science is taught in K-12 education. This shift began when the National Research Council (NRC) published *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, (hereafter referred to as “the *Framework*”). In this study report the NRC (2012) revealed several major shifts in K-12 science education. The major shift is that the *Framework* was developed to teach science from three dimensions: science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs). These three dimensions were intended to be emphasized in any science lesson or unit. Another shift in the science education is that science and engineering are equally emphasized in the curriculum. Also, science content, which was introduced in the *Framework* as DCIs, was limited to a few core ideas. The word "practices" were used instead of "inquiry" to ensure the student was immersed in an authentic educative experience (NRC, 2012). The CCCs were introduced to ensure that students will be able to find the connection between different DCIs. In 2013, a cooperation of 26 states developed the Next Generation Science Standards (NGSS) as the second stage of science education changes to determine the learning objectives for each grade level with respect to the SEPs, DCIs, and CCCs. This development was intended to ensure that students gradually progress through different grade levels.

Background of the Problem

The *Framework* serves as a foundation in defining the relationship between science and engineering challenge activities. The NRC (2012) indicates, "Engineering and technology provide a context in which students can test their own developing scientific knowledge and apply it to practical problems; doing so enhances their understanding of science" (p. 12). Thus, any engineering curriculum aligned with the NGSS is designed to improve students' conceptual understanding of science. Dankenbring, Capobianco, and Eichinger (2014) argue that any engineering design project should address one or two science concepts. Apedoe and Schunn (2013) state that, "If we are to use design-based science learning as a pedagogical approach in the science classroom, it needs to be made clear to students what the connections between design and science are" (p. 790). Emphasizing the relationship between science and engineering leads to the result that, as students work in their engineering designs, they move toward a better design solution and a better understanding of science concepts (Vattam & Kolodner, 2008). Therefore, the integration of science content in any NGSS-aligned Engineering Design Instruction (EDI) is fundamental in teachers' EDI.

The potential impact of EDI on students' science acquisition has concerned educators for many years. Dewey indicates that EDI can be utilized as a vehicle to gain scientific knowledge and that the instruction can yield other benefits. He states, "If the child realizes his instinct and makes the box, there is plenty of opportunity to gain discipline and perseverance, to exercise effort in overcoming obstacles, and to attain as well a great deal of information" (Dewey, 2001, p. 26). Enormous studies investigated the impact of EDI on students' science conceptual understanding even before the publication of the *Framework* (Cantrell, Pekcan, Itani, & Velasquez-Bryant, 2006; Mehalik, Doppelt, & Schuun, 2008; Schnittka, 2012; Schnittka & Bell, 2011), and several studies investigated the impact of engineering design on students’ conceptual understanding using NGSS-aligned curriculum (Chao et al., 2017; Marulcu & Barnett, 2016; Rehmat, 2015; Yoon, Dyehouse, Lucietto, Diefes-Dux, & Capobianco, 2014; Zhinan Huang, Jiang, & Chang, 2016). These studies conclude that EDI has the potential to improve students' achievements in science, yet they reveal mixed results in terms of the impact of engineering design on students’ achievement when compared to traditional instructional methods.

Statement of the Problem

One of the main issues with EDI is that both teachers and students face difficulties integrating science content. Capobianco (2011) believes teaching science through EDI is both challenging and complex for elementary students. Carlsen (1998) indicates that as students work in their engineering designs, they might face difficulty in linking the engineering challenge to the underlying science concepts. Also, the child, as a novice designer, is not fully able to link the engineering design problem to the underlying science concepts (Crismond, 2001). The *Framework* provides a guide for teachers to design and implement high-quality engineering curricula with rich, integrated science content. However, designing and facilitating the activities to be aligned with the NGSS is not an easy task. In-service teachers believe that the NGSS is a new pedagogical method for science that greatly influences teaching and learning (Carlson-Cassem, 2017), and it "involve[s] shifts in culture, priorities, knowledge, and allocation of resource" (Smith & Nadelson, 2017, p. 201). Science content is not integrated during specific times during the engineering instruction; however, it is intended to appear throughout different SEPs and CCCs. Teachers face difficulties in implementing the NGSS-aligned EDI as desired in the *Framework* (Marulcu & Barnett, 2016; Guzey, Harwell, Moreno, Peralta, & Moore, 2017). In terms of integrating science content into NGSS-aligned instruction, Dare, Ellis, and Roehrig (2018) indicate that teachers face difficulties making an explicit connection between science, engineering, and mathematics and in keeping their students motivated. The researchers suggest that the level of integrating different disciplines depends on teacher awareness of how to make an explicit connection. Furthermore, Chao et al. (2017) found that students tend to present how their design functions without referring to the underlying science concepts. Dare, Ellis, and

Roehrig (2014) reveal that the students' engineering decisions were not made based on their prior scientific knowledge. To conclude, the *Framework* may help teachers design and implement high-quality EDI, yet both teachers and students still face difficulties integrating science content and developing science conceptual understanding during EDI.

EDI was found to have a positive impact on students' science conceptual understanding when trained teachers implemented the activities. Therefore, a continuous effort was devoted to helping in-service teachers with the transition of aligning their instructional designs and practices to NGSS. Many professional development programs were conducted to prepare in-service teachers (Antink-Meyer & Meyer, 2016; Diefes-Dux, 2015; Marquis, 2015; Schnittka, Turner, & Colvin, 2014). These professional development workshops were found to have a positive impact on teachers' knowledge and practices, which in turn resulted in a positive impact on students' science conceptual understanding. However, several other factors, such as teachers’ educational levels and years of teaching experience, were found to play a role in their understanding and implementation of NGSS- aligned EDI after receiving professional workshops in the NGSS (Guzey et al., 2017; Hsu & Cardella, 2013; Yoon, Diefes-Dux, & Strobel, 2013)

In addition to teachers' academic preparation, teachers' self-efficacy and beliefs were extensively studied. Teachers' self-efficacy was found to be a strong predictor of teachers' instructional practice (Britner & Pajares, 2006; Coladarci, 1992; Posnanski, 2002). In more recent studies, a relationship between teachers’ self-efficacy and engineering instructional practice was confirmed (Hammack & Ivey, 2017; Marquis, 2015). Moreover, teachers' academic preparation and experience were found to serve as a source of teachers’ self-efficacy (Bergman & Morphew, 2015; Ramey-Gassert, Shroyer, & Staver, 1996; Tschannen-Moran and Hoy, 2007). Experience was also a predictor of teachers’ instructional practices. With respect to teachers’ beliefs about the importance of engineering education, studies found that in-service teachers value EDI (Hsu, Purzer, & Cardella, 2011; Rich et al., 2017; Trygstad et al., 2013; Yoon et al., 2014); however, their perceptions were subject to change when teachers gained more knowledge about and experience in teaching EDI (Haag & Megowan, 2015). Additionally, teachers perceived several barriers to facilitating EDI, including the lacking of time, resources, and professional development opportunities (Haag & Megowan, 2015; Shernoff, Sinha, Bressler, & Schultz, 2017; Smith & Nadelson, 2017; Stephenson, 2017; Wang, Moore, Roehrig, & Park, 2011).

To conclude, integrating science content into EDI was found to be an effective strategy in teaching science; however, science teachers face difficulties in developing students' science conceptual understanding through EDI. Teachers' preparation, self-efficacy, and beliefs impact EDI, but a lack of studies exist that examine the factors influencing the integration of science content in in-service teachers' EDI. Additionally, most studies that investigate the relationship between in-service teachers' EDI and students' science conceptual understanding were conducted before the formal implementation of NGSS, which might not be generalized to the new settings.

The Purpose Statement

The intent of this concurrent mixed methods study is to examine in-service elementary teachers' EDI as related to science content integration and developing students' science conceptual understanding. A cross-sectional survey was utilized to study the potential impact of teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) on elementary science teacher content integration and students' science conceptual understanding during EDI. Also, the cross-sectional survey was used to explore if there is a relationship between elementary science teachers' self-efficacy for, and beliefs about, teaching engineering design and the integration of science content and students' science conceptual understanding during EDI.

At the same time, classroom observations of EDI, open-ended questions, and content analysis of engineering instructional design explored the factors influencing the integration of science content during EDI and students' science conceptual understanding. Combining both quantitative and qualitative data served to contribute to a more comprehensive understanding of the factors influencing science teachers' EDI in developing students' science conceptual understanding.

The Significance of the Study

Engineering and science are strongly connected. EDI requires understanding and the application of science concepts. Factors affecting the integration of science content in EDI would help policymakers and schools provide the needed support for teachers to design and implement NGSS-aligned engineering curricula effectively. Understanding the relationship between teachers' academic preparation and the integration of science content provides suggestions to improve elementary preservice teachers' programs. Also, finding a relationship between professional development, teachers' experience, and teachers' beliefs and the integration of science content informs professional development to support teachers' integration of science content during EDI.

Research Questions

Research questions were formulated to include one qualitative research question, four quantitative research questions, and one mixed-methods research question.

1. (QUAL): What influences elementary in-service teachers' integration of science content into engineering design instruction and students' science conceptual understanding?

2. (QUAN): Do elementary in-service teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) influence science content integration in engineering design instruction?
3. (QUAN): Do elementary in-service teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) influence students' science conceptual understanding?
4. (QUAN): Is there a correlation between elementary in-service teachers' self-efficacy for and beliefs about teaching engineering design and science content integration in engineering design instruction?
5. (QUAN): Is there a correlation between elementary in-service teachers' self-efficacy for and beliefs about teaching engineering design and students' science conceptual understanding?
6. (Mixed Methods): Do the qualitative results reveal similar findings of the factors affecting science content integration and students’ science conceptual understanding as the findings of the quantitative analysis?

Research Design

Mixed method design is the most appropriate method to investigate the integration of science content in teachers' EDI, along with students' science conceptual understanding. Combining quantitative and qualitative methods helps to provide a comprehensive understanding of the problem. This pragmatic worldview focuses more on the research problem and uses any available approach to understand the problem (Creswell, 2009). This study employed a concurrent mixed method design; thus, the researcher collected, analyzed, and reported qualitative and quantitative data in order to address the research questions. According to

Creswell and Clark (2017), the procedure of implementing concurrent mixed methods consists of four steps: Establishing a concurrent collection of qualitative and quantitative data, analyzing each type of data separately, merging the two sets of results, and interpreting the results.

The target population of this study was elementary in-service teachers who teach in the state of Kansas. The researcher randomly selected a single school district for each county in the state of Kansas. The survey was distributed to all elementary in-service teachers in the selected school. The survey collected quantitative data (Likert, selected response) and qualitative data (open-ended question). Also, the participants were asked permission for the researcher to conduct classroom observations. Follow-up emails were sent to the participants who agreed.

The data was divided into two categories. For the quantitative data, a descriptive analysis of each variable included in this study design was reported. Then, the researcher ran multivariate analysis of variance (MANOVA) to investigate the impact of teachers' preparation on science content integration in EDI and students' science conceptual understanding. Also, a correlation test was conducted to examine the relationship between teachers' self-efficacy for, and beliefs about, teaching engineering design and the integration of science content and students' science conceptual understanding. Qualitative data that was collected from open-ended questions, classroom observations, and documents analysis was analyzed using analytical tools suggested by Strauss and Corbin (1998), which are open coding, axial coding, and selective coding.

The final step of this research design was merging the two types of results as suggested by Creswell and Clark (2017). Therefore, during this phase, the researcher summarized the two results, discussed the how the two data sets were related to each other, and explained divergence between the two results.

Theoretical Framework

The framework for this study design assumes that the integration of science content in teachers' EDI is a behavior influenced by both personal and environmental factors. Students' integration of science content during EDI is the environmental influence established by teachers' behaviors. The overarching theory of this study is social cognitive theory. Bandura (1989) states, "reciprocal causation, behavior, cognition and other personal factors, and environmental influences all operate as interacting determinants that influence each other bidirectionally" (p. 2). Personal factors such as cognitive beliefs, self-efficacy, and perception, along with environmental factors such as physical and social factors, shape teachers' behavior; however, teachers' personal factors and the environment may not have an equal influence on each other (Bandura, 1989). Thus, this study was designed to investigate the different impacts of personal and environmental factors on the integration of science content in teachers' EDI. See Figure 1.1.

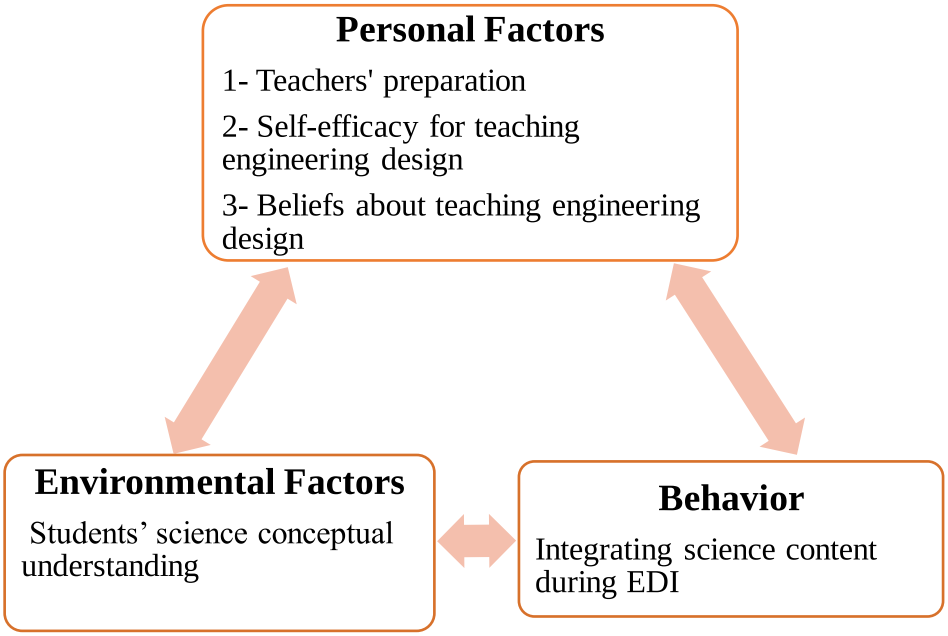


Figure 1.1. The theoretical framework for the factors affecting the integration of science content during EDI and students' science conceptual understanding.

Self-efficacy is a major component of social cognitive theory. Bandura defined self-efficacy as "people's beliefs about their capabilities to produce designated levels of performance" (Bandura, 1994, p. 71). According to Bandura (1997), people develop self-efficacy from their mastery experience, vicarious experience (observing how people similar to you succeed), social persuasion, and their physiological reactions to a situation. Researchers uncovered a relationship between self-efficacy and teachers’ instruction (Coladarci, 1992; Sandholtz & Ringstaff, 2014; Vieluf, Kunter, & Vijver, 2013). Thus, it is important to investigate the elementary teachers' self-efficacy as a personal factor that may predict the teachers' behavior in integration of science content during EDI.

In the application of social cognitive theory to this study, science integration in teacher EDI and students' science conceptual understanding were defined in the following manner:

1. The integration of science content in teachers' engineering instructional practices is a "behavior" influenced by teachers' preparation and beliefs (personal factors).
2. Students’ utilization of science content during the engineering design is "environmental impact" and exists because of the regular integration of science content in teachers’ engineering instructional practices (behavior).

The following statement represents the underlying logic for the design of the study. If elementary in-service science teachers: (a) are academically prepared; (b) have experience teaching engineering design; (c) have high self-efficacy; (d) value the importance of elementary engineering education; and (e) have a supportive school environment, then they will integrate and assess science content into their EDI, and increase students' science conceptual understanding.

Limitations

Limitations to this study include the following:

1. Validation of the modified survey was not established.
2. Students' backgrounds, such as prior science achievement, were not taken into considerations.
3. Classroom observations and documents analysis are limited by the researchers' interpretations.
4. The study is limited to voluntary participants.
5. The qualitative data collected via the survey was limited to the teachers' willingness to comment.

Delimitations

Delimitations to the study include the following:

1. Quantitative and qualitative data were collected from all participants. All participants were asked to answer open-ended and close-ended questions that were analyzed as qualitative and quantitative data.
2. The study was designed to investigate EDI that aligns with the NGSS. Since these standards were developed by 26 states and are currently officially implemented in 18 states, the researcher assumed that most schools were in the transition period of preparing in-service teachers for the NGSS.
3. The target population is elementary in-service teachers. It was found that elementary teachers are less prepared to and lack the confidence to teach NGSS-aligned curricula. Also, elementary students struggle more with integrating science content when compared to middle and high school students, according to Capobianco (2011).

4. The instrument used to investigate teachers' beliefs captured the importance of engineering education as perceived by elementary teachers. The value of the subject determined teachers' effort to teach that subject.
5. The study investigated limited numbers of engineering teaching perceived barriers found in the literature using Likert type scale instrument.

Terms and Definitions

Academic preparation. Actual science and engineering coursework completed by in-service teachers during undergraduate or graduate studies.

Engineering design instructions. A method of instruction used to teach engineering design through a process that begins with the identification of a problem, then imagine solutions, plan designs, create, test and improve models, and end with a solution

Engineering teaching self-efficacy. Teachers' beliefs in their abilities to facilitate EDI.

Integration. 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).

Perceived barriers. Any obstacle elementary teachers perceive as they teach NGSS-aligned EDI.

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

Self-efficacy. "Beliefs in one's capabilities to organize and execute the courses of actions required to produce given attainments" (Bandura, 1997, p. 3).

Summary

The purpose of this study is to understand the factors that influence elementary in-service science teachers in using engineering design as a portal to develop students' science conceptual understanding. Based on the theoretical framework, different personal factors have an unequal impact in predicting the behavior of integrating science content in EDI. Furthermore, based on the literature, two main factors seem to have an effect on science content integration in EDI: teacher preparation (academic preparation, degree level, engineering design teaching experience, professional development); and self-efficacy of, and beliefs about, teaching engineering design. Therefore, the researcher designed this study to include and investigate the suggested variables. Chapter 1 included an introduction to the research topic, where the researcher stated the research problem, offered a review of studies that have addressed the problem, indicated the deficiencies in the studies, and stated the purpose of this project. Also, this chapter contains the research questions and offered a discussion of the research framework, the limitations, delimitations, and the definitions.

The next chapter reviews and discusses the literature related to the study. The literature review begins with an introduction to NGSS, the transitions to the new standards, and the connection between the NGSS and EDI. Also, the literature review discusses the *Framework*, teachers’ pedagogical content knowledge (PCK), and the integration of science content. In addition, the second chapter reviews the literature about teachers' preparation (academic preparation, professional development, and experience) and beliefs (self-efficacy, perception toward the importance of engineering education, and the barriers of implementing engineering education). Finally, Chapter 2 reviews the study and investigates the impact of EDI on students' science conceptual understanding.

Chapter 2 - Literature Review

The NGSS were officially adopted in 18 states (K. Harris, Sithole, & Kibirige, 2017). The importance of engineering education for K-12 was raised to the same level as science inquiry (NRC, 2012); thus, in-service science teachers in these states are in charge of designing and teaching engineering-based lessons as a vehicle to develop students' science conceptual understanding. It has been suggested that both preservice teacher programs and in-service teacher professional development programs need to be reformed to include more science and mathematics courses, as well as engineering design process (EDP) (Lee & Strobel, 2014), to ensure a smooth transition to the NGSS. The NRC (2012*)* indicates that professional development is necessary to help in-service teachers design and implement curriculum as desired. Trygstad et al. (2013) indicates that states, districts, and schools face a significant challenge to adopt the NGSS. At the state level, many workshops were conducted to ensure a smooth transition to the new approach of teaching science (Dare, Ellis, & Roehrig, 2014; Diefes-Dux, 2015; Guzey, Tank, Wang, Roehrig, & Moore, 2014; Haag & Megowan, 2015; Schnittka, Turner, & Colvin, 2014). These workshops positively influence teachers' perceptions toward the importance of engineering education (Marquis, 2015; Smith & Nadelson, 2017; Yasar, Baker, Robinson-Kurpius, Krause, & Roberts, 2006), self-efficacy (Posnanski, 2002; Peter Jacob Rich, Jones, Belikov, Yoshikawa, & Perkins, 2017), and teachers' pedagogical content knowledge (Schnittka et al., 2014). However, a national study indicates that in-service teachers reported that they are not fully prepared for the NGSS, especially in teaching engineering (Haag & Megowan, 2015). In this study, the researcher examines the factors that influence the integration of science content in EDI. The researcher uses the *Framework* as a reference to assess the degree to which science content is supposed to be integrated into EDI. Therefore, as the researcher discusses the factors influencing the best instructional practices of implementing the NGSS curricula, the researcher assumes the best EDI reflects an ideal integration of science content.

Self-Efficacy, Belief, and Perception

The factors influencing the integration of science content in EDI are complex. As previously mentioned, in-service teachers' instructional practices were found to be affected by their experience, academic preparation, and in-service professional workshops. Other factors, such as self-efficacy for and beliefs about teaching engineering design, were strongly influenced by teachers' preparation and could predict the teachers’ behavior. Pajares (1992) argues that there is “a strong relationship between teachers’ educational beliefs and their planning, instructional decisions, and classroom practices” (p. 326). Bandura (1989) indicates that past experience (mastery experience) is a source of self-efficacy, and self-efficacy is a strong predictor of one behavior. His theory suggests that teachers’ academic preparation and experience in teaching engineering design curricula shape their teaching self-efficacy, which predicts how well they effectively teach engineering design. Teachers’ beliefs about teaching engineering design is another factor that influences one’s behavior and is influenced by other factors such as educational background and experience. Haney, Czerniak, and Lumpe (1996) indicate that science teachers’ beliefs are strong predictive factors of how well teachers intend to embrace the new reform of science education. Pruitt (2015) notes that the science education community shows excitement about the NGSS, and many school districts in non-adopting states are embracing it.

Beliefs About Teaching Engineering Design

Teachers’ beliefs about teaching engineering design may influence their EDI. Bryan and Atwater (2002) state, "The value that a teacher places on course content may influence how the person teaches the content" (p. 824). Teachers who value the engineering education might allocate more time and effort to effectively implement EDI. This assumption was emphasized in Bandura's (1989) social cognitive theory. He states, "What people think, believe, and feel, affects how they behave" (p. 3). A large body of research was conducted to investigate in-service teachers' perceptions toward the importance of teaching engineering design (Hsu, Purzer, & Cardella, 2011; Rich et al., 2017; Trygstad et al., 2013; Yoon et al., 2014). These studies reveal that in-service teachers value the effect of teaching engineering design. Also, teacher perception was found to positively change as the teacher became more familiar with and received training to implement engineering design (Haag & Megowan, 2015).

Using an instrument developed by Yaşar et al. (2006), a study was conducted to explore elementary teachers' familiarity with and perception toward design, engineering, and technology (DET) (Hsu, Ming-Chien; Purzer, Senay; and Cardella, Monica E., 2011). Results indicate that teachers believe that DET is important. Hammack and Ivey (2017) investigated a representative sample of science teachers in the state of Oklahoma using the same instrument and found that teachers value elementary engineering education. Another study used the same instrument to investigate the teacher perception change toward engineering design after professional development was implemented, and the results did not find a significant change in teachers' perception toward engineering design (Yoon, 2013). More than 700 teachers across the United States participated in a national study, and the results revealed that teachers are motivated to implement SEPs. However, the study found that high school teachers are more motivated and prepared to implement SEPs compared to middle school teachers. The study also concludes that trained teachers are more motivated and prepared to implement NGSS-aligned instruction (Haag & Megowan, 2015).

Wang et al. (2011) conducted a multiple-case study to investigate the connection between teachers' perception and practices. The results indicate that teachers in different disciplines have different perceptions of integrating science, technology, engineering, and mathematics (STEM) content, which influence their practices. The study indicates that teachers gave positive feedback regarding the potential impact of STEM integration on students' confidence level. Also, it was found that teachers believe implementing STEM design challenges can increase students' achievement in science, mathematics, and engineering practices (Lesseig, Nelson, Slavit, & Seidel, 2016).

Self-Efficacy for Teaching Engineering Design

Numerous studies found a relationship between teachers' self-efficacy and their instructional practices (Britner & Pajares, 2006; Coladarci, 1992; Posnanski, 2002). Also, researchers investigated the factors that influence teachers' self-efficacy and found that teachers' successful experience in teaching and prior science knowledge is a predictive factor influencing science teachers' self-efficacy. Bandura (1989) identified four sources of self-efficacy: mastery experience, vicarious experience, verbal persuasion, and physiological arousal. Tschannen-Moran and Hoy (2007) investigated the differences between novice teachers and experienced teachers and found that mastery experience is a strong predictor of one's self-efficacy. Britner and Pajares (2006) conducted a study to investigate the impact of mastery experience on middle school students, and the results indicate that mastery experiences significantly predicted self-efficacy in science. However, a study found that teachers' self-efficacy significantly declined during the first year of teaching due to the lack of appropriate support from the school (Hoy & Spero, 2005). Therefore, a successful experience in teaching engineering design and support from the school are expected to improve engineering teaching self-efficacy, which will result in effective EDI.

Researchers investigated the impact of science content course on science teachers' self-efficacy. The results indicate a relationship between high-quality science content courses and teachers’ self-efficacy (Bergman & Morphew, 2015; Ramey-Gassert, Shroyer, & Staver, 1996). One study was conducted to investigate the effect of a science content course on elementary preservice teachers' self-efficacy of teaching science. There were 154 preservice teachers who participated in the study. The results indicate that a science content course significantly influenced their self-efficacy for teaching science (Bergman & Morphew, 2015). Ramey-Gassert et al. (1996) conducted a qualitative study to investigate the factors that influence science teacher self-efficacy, and the results indicate teachers’ successful science learning experience during college coursework and in-service workshops ensure high self-efficacy.

Many researchers tend to measure teachers' self-efficacy after conducting a professional development workshop to help predict the impact of the workshop on teachers' instruction. Posnanski (2002) indicates that professional development workshops are an effective factor in improving teacher self-efficacy. Marquis (2015) conducted a study to investigate the impact of professional development on teacher pedagogical content knowledge teaching engineering design to K-5 students. The results indicate a significant improvement in teachers' self-efficacy. However, in relation to teaching engineering self-efficacy, a recent study indicates that teachers have low engineering self-efficacy (Hammack & Ivey, 2017), which may predict the effectiveness of their EDIs.

Perceived Barriers

Many studies investigate the obstacles limiting teachers’ EDI and conclude that teachers’ perceived barriers include limited time for engineering instruction, poor quality of the engineering curricula, lack of training opportunities, lack of teaching confidence, lack of necessary skills and knowledge, and lack of cultural support (Haag & Megowan, 2015; Shernoff, Sinha, Bressler, & Schultz, 2017; Smith & Nadelson, 2017; Stephenson, 2017; Wang, Moore, Roehrig, & Park, 2011). Even though these studies used different research methods such as surveys, case studies, and mixed methods to investigate in-service teachers' perceived barriers, the results are consistent.

Haag and Megowan (2015) conducted a national survey and found that 68% of middle school teachers believe that the limited time allocated for the instructional practices is a barrier to successful NGSS implementation. Stephenson (2017) conducted a case study to investigate teacher perceived barriers related to teaching science. Fifteen elementary teachers participated in the study. Stephenson found that teachers' perceived barriers include limited time for science instruction in addition of lack of teaching confidence, few professional development opportunities, and concerns about the state standards and lack of resources. Another case study was conducted to investigate teachers' beliefs and perceptions toward STEM integration. Three teachers participated in the study. The teachers believed that science, engineering, and mathematics are related in a natural way; however, they identified the lack of both technological resources and high-quality STEM curricula as the biggest obstacles (Wang et al., 2011). In addition, Shernoff et al. (2017) examined the teachers' perceived barriers as a part of investigating the impact of professional development in implementing the NGSS aligned curriculum. The results reveal that the most common challenge for the participants is the limited time for instructional design and practices. Also, the teachers indicated the lack of adequate skills and knowledge as a challenge. To conclude, in-service teachers are facing several challenges preventing them from effectively implementing EDI that aligns with NGSS, which may lead to the conclusion that these barriers impact the integration of science content during the EDI.

The Framework for K-12 Science Education

The NRC (2012) emphasized that K-12 science education in the United States has failed to equip students with the necessary skills and knowledge in science and engineering. Today, the world is facing many challenges in terms of the environment, energy consumption, and health. Any economic, social, or political solution requires a deep knowledge of science and engineering (NRC, 2012). These issues led to the publication of the *Framework*, which reformed science education in the United States. The *Framework* set the performance expectations of what K-12 students should know and be able to do with respect to science and engineering. The second phase of science education reform was the development of the NGSS, which was developed through the cooperation of 26 states (Bybee, 2014). The NGSS determines students’ performance expectations for each grade level. These standards simplify and clarify what the students should know and be able to do by the end of each grade level (NRC, 2013).

The *Framework* recognizes three dimensions that need to provide students with an effective science education (NRC, 2013). The three dimensions provide an opportunity for the students to learn science content, understand how scientific knowledge is acquired and used, and discover how science concepts are relevant across different science disciplines. Therefore, investigating the integration of science content in EDI requires a close look at each dimension to understand how the science content is supposed to appear in teachers' instructional design and practices, as well as in the students' actions. The following are the three dimensions as introduced in the *Framework.*

Dimension 1: Practices

The word "practices" was introduced in the *Framework* to describe "the major practices that scientists employ as they investigate and build models and theories about the world" (NRC, 2012, p. 30) and the set of engineering practices used by engineers during the design process. This dimension was emphasized in the *Framework* to ensure that students will themselves engage in engineering and science practices that help them appreciate the nature of scientific knowledge (NRC. 2012). As stated in the NRC, "Science is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge" (2013, p. 26). These practices are the strategies used to help students develop and apply a scientific understanding of a phenomenon. Therefore, the integration of science content permeates these practices. The *Framework* identified eight practices as essential elements of the K-12 science and engineering curriculum. The researcher highlights and explains the practices related to the engineering practices.

1. **Asking questions and defining problems**. Students identify the problem that needs to be solved and ask a question to help to determine the constraints and specifications of the solution.
2. **Developing and using models**. This practice may include different types of model representations to include diagrams, physical models, mathematical representations, analogies, and computer simulations; students at the elementary level may progress from presenting a car toy as a model to more abstract models (NRC, 2012).
3. **Planning and carrying out investigations**. Students identify the variables that need to be taken into consideration, how the data will be collected, and the tools needed for the investigation.

4. **Analyzing and interpreting data**. Students analyze their engineering design after creating a prototype and collecting extensive data on how models perform under different conditions.
5. **Using mathematics and computational thinking**. Students use mathematical models to test and predict the performance and limitations of their engineering design product.
6. **Constructing explanations and designing solutions**. Students construct and implement their design solution based on the plan that meets specific design criteria.
7. **Engaging in argument from evidence**. Students identify the best design solution and discuss the strengths and weaknesses of the design.
8. **Obtaining, evaluating, and communicating information**. Students learn to represent their work in different scientific formats such as words, diagrams, charts, graphs, images, symbols, and mathematics.

All of these engineering practices are important during the EDI, yet the practices are not taught in a linear manner or in isolation during EDI. For example, the first and eighth practices may occur simultaneously. Also, each practice has multiple levels of sophistication. For example, using modeling practices for students at the elementary level might be limited to using a picture of a toy (NRC, 2012). The NGSS determined the sophistication level of practices that should be introduced to elementary students. The primary difference between science practices and engineering practices is that science practices help students build understanding while engineering practices help students apply their understanding by building an engineering design (Antink-Meyer & Meyer, 2016). Scientists use engineering design as a part of their scientific practices in order to understand certain phenomena; also, engineers use scientific knowledge to solve their engineering problems. Therefore, this study investigates the integration of science content during EDI by investigating the targeted science phenomena planned and addressed by the teachers and how students develop and apply scientific understanding during SEPs.

Furthermore, students are encouraged to use a model of EDP to guide them during engineering design activities. According to Hill-Cunningham, Mott, and Hunt (2018), EDP encompasses the fundamental steps that guide engineers to solve a problem. In any EDI, students are required to follow the EDP to strengthen their understanding of open-ended design with multiple solutions (Garcia, 2016). Also, incorporating EDP increases students' motivation, engagement, and enjoyment of science (Macalalag, Lowes, McKay, Guo, & McGrath, 2009). There are several models developed to describe the EDP. According to "Engineering Design Process Models," (n.d.), the Massachusetts Department of Education developed a model that consists of eight steps. The Museum of Science, Boston developed a model for elementary students that consists of five steps, including ask, imagine, plan, create, and improve. The National Center for Engineering and Technology Education developed a model of EDP that consists of eight steps with an indication of how the students may jump back and forth between some steps. It is noteworthy that EDP is not a linear process but a constant back and forth of questioning, creating, and optimizing (Hill-Cunningham et al., 2018).

Dimension 2: Crosscutting Concepts

The *Framework* identifies seven CCCs to help students develop a cumulative understanding of science and engineering. Fick (2018) investigated the role of CCCs during the implementation of NGSS-aligned lessons and indicates that the CCCs explicitly frame students' discussion about a phenomenon and help to highlight students' understanding. The *Framework* listed seven CCCs as follows:

1. Patterns

2. Cause and effect: mechanism and explanation

3. Scale, proportion, and quantity

4. Systems and system models

5. Energy and matter: flows, cycles, and conservation

6. Structure and function

7. Stability and change

Students repeatedly use these CCCs with the context of DCIs and SEPs. In other words, these CCCs cannot be isolated; they were found to link different domains of science (NRC, 2012). The *Framework* provided an example in how “pattern” as a crosscutting concept is introduced during the EDI through the statement, “Noticing patterns is often a first step to organizing and asking scientific questions about why and how the patterns occur" (NRC, 2012, p. 85). As students observe a phenomenon, they are encouraged to find if there is a pattern, which will trigger their curiosity to ask a question. In relation to this study, the CCCs are strongly connected to science content and serve to explicitly explain the underlying science phenomena during the EDI; therefore, these concepts are closely investigated in this study.

Dimension 3: Disciplinary Core Ideas

During K-12, students will have the opportunity to learn limited sets of core ideas that help them acquire additional scientific information independently (NRC, 2012). The NRC (2012) indicates that students who learned sufficient core knowledge and practices will become independent when they finish high school. The *Framework* identified four DCIs:

1- Physical sciences: Matter and its interactions; motion and stability; energy; and waves and their applications in technologies for information transfer.

2- Life sciences: Structures and processes; ecosystems, interactions, energy, and dynamics; heredity, inheritance and variation of traits; and biological evolution, unity, and diversity.
3- Earth and space sciences: Earth's place in the universe; Earth's systems; and Earth and human activity.
4- Engineering, technology, and application of science: Engineering design and links among engineering, technology, science, and society.

These DCIs were developed based on several criteria: 1) they have a broad application; 2) they are essential to help students understand more complex phenomena or solve problems; 3) they are relevant to the students; and 4) they can be taught over multiple grades by having multiple levels of depth (NRC, 2012).

To conclude, the publication of the *Framework* drastically changes how science content is taught, leading to formal implementation of elementary engineering education, emphasizing the connection between engineering and science, and defining how science content could be integrated into EDI. The three dimensions are taught together. Students are guided to look for a pattern (a crosscutting concept) as they observe phenomena (a disciplinary core idea) to identify a problem or develop a question (science and engineering practice). Furthermore, adding engineering as content and practice, reducing the number of DCIs, and including the CCCs shift how science content is presented to students. This may suggest that teachers should be academically and pedagogically prepared to effectively integrate science content into NGSS-aligned EDI.

Pedagogical Content Knowledge

As previously discussed, the science content is thoroughly embedded in all three dimensions. Therefore, the best practices of implementing NGSS-aligned curriculum ensure an ideal integration of science content. As a result, in-service teachers' pedagogical content knowledge in implementing a well-aligned NGSS curriculum will lead to an appropriate integration of science content. The term pedagogical content knowledge (PCK) appeared for the first time in Shulman's (1987) work. He argues that content knowledge alone is not enough for effective teaching. He conducted two case studies to compare expert and novice teachers and found novice teachers may have sufficient content knowledge, but the limited pedagogical knowledge impacts their ability to become more effective. He defined PCK as "a form of teacher understanding that combines content, pedagogy and learner characteristics in a unique way" (p. 59). Van Driel, Verloop, and de Vos (1998) identified two key elements of PCK, which are "knowledge of a representation of subject matter" and "understanding of learning difficulties and student perception" (p. 675). Usually novice teachers are experts in the content when they graduate from the university; however, they fail to deliver that knowledge to students because of their lack of experience in pedagogy. PCK emphasizes two factors that lead to effective learning outcomes: Selecting appropriate instructional methods for teaching and understanding students' characteristics. According to Van Driel, Verloop, and de Vos (1998), PCK is usually developed through experience, and the novice teacher usually has little or no PCK. Also, Van Driel, Verloop, and de Vos (1998) indicate that when teachers teach unfamiliar topics, they face some difficulties dealing with new potential issues and struggle with selecting an appropriate presentation for the subject matter. Appleton (2003) found that novice elementary science teachers tend to avoid teaching science and suggest that "science avoidance, in part, is a consequence of the teachers' limited science PCK" (p. 15). Implementing EDI to K-6 students is relatively new. Many in-service teachers who are now in charge of implementing NGSS-aligned curricula had never been exposed to this type of pedagogical method when they were students;

thus, developing PCK for teachers may take time. Mecol (2013) indicates that novice teachers who received a high-quality teacher education are more likely to develop substantial PCK in comparison to novice teachers who did not. Cotabish, Dailey, Robinson, and Hughes (2013) indicate that the quality of the professional development program influences teachers’ PCK. Schnittka et al., (2014) found that professional development workshops have a positive impact on teachers' PCK. Therefore, the literature in PCK suggests science teacher preparation should be included as a factor that influences the integration of science content in EDI and students’ conceptual understanding.

Science Teacher Preparation

Academic Preparation

Many studies reveal the impact of teachers’ academic preparation on teaching effectiveness. Teachers’ academic preparation is commonly investigated by looking at teachers’ majors and minors, certifications, and advanced degrees (Laczko-Kerr & Berliner 2002). Bolyard and Moyer-Packenham (2008) reviewed the literature on the quality of mathematics and science teachers and concluded that there is a link between subject matter preparation and students’ achievement; however, the relationship is not always consistent. Darling-Hammond (2000) surveyed 65,000 teachers across 50 states to investigate the link between teachers' quality and students' achievement. The researcher states, "Teacher quality characteristics such as certification status and degree in the field to be taught are very significantly and positively correlated with student outcomes" (p. 23). In addition, data from the National Educational Longitudinal Study of 1988 was used to measure the impact of teacher academic degree levels on educational performance. Approximately 24,000 eighth-grade students participated in the study. The results indicate that teachers with BA degrees in science have a significant positive effect as compared to those who have BA degrees in another subject (Goldhaber & Brewer, 1996). Teachers' certifications serve as an indicator of teacher academic preparation. Hawk, Coble, and Swanson (1985) found that certified teachers have more subject matter knowledge, which led to a positive impact on student achievement. They indicate that certified teachers tend to implement more effective instructional practices while LaTurner, (2002) indicates that certified teachers tend to have more commitment to teaching science. Moreover, Laczko-Kerr and Berliner (2002) measured the impact of certified teachers on students' achievement compared to uncertified teachers and found that students of non-certified teachers experience 20% less academic growth per year compared to those who are taught by certified teachers.

Furthermore, academic coursework was found to be a predictive factor of effective teaching (Ferguson & T. Womack, 1993). However, a single introductory course in the subject may not be enough to prepare teachers to teach science. McDermott (1990) argues that taking an introductory college level course alone does not prepare teachers to teach high school because introductory college courses usually provide general information and do not allow learners to grasp the underlying concepts. She indicates that an introductory course is usually delivered in lecture format and does not help learners to develop better reasoning ability to help them answer any unexpected question. Therefore, it is necessary to investigate teacher academic preparation with respect to the introductory college coursework and any other advanced courses related to the same subject.

A national longitudinal study analyzed data gathered from 24,000 students in the eighth grade and found that teachers' academic preparation positively influences students' outcomes in science (Chaney, 1995). Also, it was found that the gap in teacher content knowledge limited their motivation to teach science (Appleton, 2003). In relation to teaching engineering design, Baker, Yasar-Purzer, Kurpius, and Krause (2007) investigate the impact of a graduate course on integrating DET on teacher instructional practices. Three graduate teachers participated in the study. The data was collected through open-ended pre/post question, seven reflections, interviews, and an analysis of a unit developed by the three teachers. The study indicates that the course changes the teachers' instructional practices to become more effective, noting that teachers "need support in seeing how DET already exists in their own curriculum" (p. 891), which emphasizes the importance of science teachers taking an engineering design in science methods course as a part of their academic preparation. Furthermore, Yoon, Diefes-Dux, and Strobel (2013) investigated the impact of one year of professional development on in-service teachers and found that teachers' knowledge about EDP significantly improved; however, teachers' knowledge improvement significantly differed by the participant educational level. The knowledge of teachers with a Ph.D. and/or a master's degree significantly improves after the workshop as compared to teachers with only a bachelor's degree. This result suggests that both teachers' educational level and professional development workshops should be included in the investigation of the integration of science content during the engineering instructional practice.

Professional Development

A large body of research was conducted to examine the impact of professional development on teachers' instructional practices and students' learning outcomes (Blank, de las Alas, & Smith, 2007; Garet, Porter, Desimone, & Birman, 2001; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009; Wenglinsky, 2000). These studies report that professional development has a positive influence on teacher's practices and students' learning outcomes. Wei et al. (2009) state, "Efforts to improve student achievement can succeed only by building the capacity of teachers to improve their instructional practice and the capacity of school systems to advance teacher learning" (p.1). Policymakers and schools value the importance of providing professional development to in-service teachers. It was suggested that all teachers in every grade level and in every subject should receive high-quality sustained professional development throughout the school year (Wei et al., 2009). More than $3 billion was allocated for professional development in the United States (Wei et al., 2009), yet over 60% of elementary teachers self-reported that they received less than six hours in science professional development in the last three years (Trygstad et al., 2013). Wei et al. (2009) also indicate that not all teachers receive high-quality professional development. This suggests that in-service teachers across the United States have varied opportunities in terms of the number of and the quality of professional development they receive.

Garet et al. (2001) surveyed 1,027 mathematics and science teachers to identify the characteristics that make professional development effective and suggest that any professional development that provides active learning, focuses on a specific subject matter, and integrates these trainings throughout the school year is more likely to become effective. Wei et al. (2009) indicate that professional development becomes more effective when the trainings focus on specific pedagogical skills in teaching specific content. Blank et al. (2007) conducted a meta-analysis study to investigate the impact of content focused professional development on students' achievement in science and math. The researchers identified 16 empirical studies. Four out of the 16 studies reported on science professional development trainings and 12 reported on those in math. The study concluded that this type of professional development positively influences students' achievement. Wenglinsky (2000) conducted a study by analyzing data from the National Assessment of Educational Progress (NAEP). The purpose of the study was to explore the factors influencing classroom practices and student achievement. The results indicate that professional development is a critical factor, one that positively influences teacher instructional practices and student achievement in mathematics and science. However, Telese (2008) conducted a study by analyzing data from the NAEP, and the results indicate that students whose teachers received a large extent of professional development training were associated with lower achievement scores. Telese (2008) suggests that mathematics teachers should receive a limited amount of professional development.

Several studies investigate the impact of professional development on teachers' engineering instructional design, practices, self-efficacy, perception, and students' achievement. The results indicate that professional development has a positive impact. Shernoff, Sinha, Bressler, and Schultz (2017) conducted a case study of 17 teachers and concluded that the professional development had a significant impact on teachers’ conceptual understanding of NGSS, which results in a pedagogical shift as required for the NGSS. Tuttle et al. (2016) conducted a mixed method study to investigate the impact of two-week professional development trainings that were designed to help in-service teachers design and implement lessons aligned to NGSS. The results indicate that two weeks of professional development significantly improves preK-3 teachers' knowledge and practices. A professional development that was supported by the Alabama State Department of Education was conducted, and the results of the study indicate that teachers' self-efficacy increased significantly(Schnittka et al., 2014. Also, studies found professional development has a positive impact on teachers' familiarity and perception (Dare et al., 2014; Matthews, 2013). Teachers tend to implement the same activities learned in the workshop to their students several times after the workshop is finished (Haag & Megowan, 2015). Preparing teachers for the NGSS, which helps them effectively integrate science content into their EDI, requires a more sustainable professional development program. Haag and Megowan (2015) indicate that completing 90 hours on average of workshops is more likely to prepare in-service teachers for NGSS. However, a study found that professional development may have a different impact on teachers' actual implementation of NGSS aligned curriculum. Shernoff et al. (2017) analyzed the teachers' written lesson plans and found that teachers reveal less conceptual understandings of NGSS aligned curricula compared to what they report.

Teacher Experience

Many studies investigated the impact of teaching experience on teachers' effectiveness. The relationship between years of teaching experience and students' learning outcomes is not always consistent (Darling-Hammond, 2000). According to Kraft and Papay (2014) in the past, researchers tend to believe that teachers' productivity tends to improve during the first few years only. Darling-Hammond (2000) explains that older teachers do not always choose to improve themselves, which results in a curvilinear trend of the relationship between teaching experience and effectiveness, while Kraft and Papay (2014) argue that a cross-section survey fails to detect the continued improvement of teachers' effectiveness because attrition was ignored. Kraft and Papay (2014) state, "Even if teachers do improve with experience, we can find flat returns to experience in the cross-section if the most effective teachers leave" (p. 2) This may explain why some studies did not find a significant relationship between teacher experiences and teaching effectiveness.

Five studies found that teachers' improvement continues beyond the first five years (Boyd, Lankford, Loeb, Rockoff, & Wyckoff, 2008; Harris & Sass, 2011; Kraft & Papay, 2014; Ost, 2014; Wiswall, 2013). These studies agree that during the first years of teaching, the relationship between teachers' years of experience and students' achievements is significant.

Wiswall (2013) conducted a study to investigate the relationship between teacher experience in public school and students' outcomes. The data was collected from all fifth grade classes in the state of North Carolina. The researcher concluded that teachers continue to improve during the course of their careers. He found that experienced teachers positively influenced students' achievement in mathematics. A similar study, a longitudinal study that gathered information about students, teachers, school characteristics, and standardized test results of the students, indicates that teachers who have taught in a specific grade level have a positive impact on student math achievement compared to those who taught in different grade levels (Ost, 2014). In science, Druva and Anderson (1983) conducted a meta-analysis study and found that a positive relationship exists between years of teaching experience and students' achievement in science; however, the relationship was not strong.

Elementary teachers were found to be continually improving their capacity in teaching. Harris and Sass (2011) investigated the impact of elementary teachers' experience. The results indicate that in the first few years, elementary teacher productivity increases rapidly, and their productivity continues improving beyond the first five years of their careers. In a similar study, Wiswall (2013) investigates the impact of elementary teachers' experience and found a relationship between years of elementary teaching experience and students' outcomes. Over 200,000 students and 3,500 teachers participated in a study in which researchers concluded that teachers continue to improve their productivity after the first years of teaching experience (Kraft & Papay, 2014). Another study was conducted in New York City, and the results indicate that teachers continue to positively influence students' outcomes during the first five years of their careers (Boyd et al., 2008). Tella (2017) investigated the impact that years of elementary teaching experience had on students' achievements, yet did not find a correlation.

In relation to the link between effective EDI and teacher experience, Guzey, Harwell, Moreno, Peralta, and Moore (2017) found a negative correlation between teachers' experience and student achievement and suggest, "Changing classroom practices are established over the years, and replacing a traditional science curriculum with an engineering-focused curriculum may not be easy for many experienced science teachers" (p. 222). However, Hsu and Cardella (2013) investigated the difference in EDI during the EDP between experienced teachers and new teachers. Fifty-nine in-service elementary teachers participated in this study. The results indicate that teachers who have experience in teaching engineering design are more aware of the time during the activity, which results in more effective EDI, Therefore, it is important to include the years of teaching experience in general and experience of teaching engineering design when investigating the factors influencing the integration of science content in teachers' instructional practices.

Finally, the *Framework* does not simply add engineering to the curriculum; rather, it frames science education to be taught from three dimensions. Teachers are the key component to implementing the new standards. A genuine implementation requires teachers to be academically prepared through their academic studies and the professional development program. Further, the implementation requires that teachers gradually increase their experience in teaching engineering design, which results in positive beliefs toward engineering education and an effective integration of science content.

Engineering Design and Student Achievement

EDI is a widely known approach to teaching science in the United States, especially after the formal implementation of the NGSS. Many studies were conducted to investigate the impact of EDI on students' science conceptual understanding (Bethke Wendell & Rogers, 2013; Cantrell et al., 2006; Chao et al., 2017; Marulcu & Barnett, 2016; Mehalik et al., 2008; Rehmat, 2015; Schnittka & Bell, 2011; Zhinan Huang et al., 2016). The results indicate that EDI tends to improve students' science conceptual understanding; however, some studies reported that EDI is just as effective in improving students' science content achievement as traditional science instruction (Marulcu & Barnett, 2016; Zhinan Huang et al., 2016).

Several studies have found a significant impact of EDI on students' science achievements when compared to the traditional methods. Rehmat (2015) conducted a study to measure the impact of problem-based learning on students' learning outcomes compared to traditional methods of teaching science. The NGSS-aligned curriculum was given to the treatment group. The results indicate that students' STEM knowledge significantly improved after the intervention in both groups; however, students who received the NGSS-aligned curriculum outperformed students who received traditional instruction. In a similar study, Yoon et al. (2014) investigated the impact of EDI on students' achievement compared with the traditional approach. A total of 831 students and 59 elementary teachers participated in the study. The results indicate that EDI has a significant impact on students' achievement compared to the traditional approach. A single engineering-based unit revealed significant effects on students' content knowledge, which denotes the potential impact of the engineering curricula (Yoon et al., 2014)

Furthermore, the material used in the EDI plays an important role in developing students' science conceptual understanding. Chao et al. (2017) conducted a mixed method study to investigate the impact of a rich tools environment on EDI, and 83 students participated in the study. The researcher intentionally minimized social interaction and direct instruction to ensure that any science achievement came from student interactions with the tools. The findings indicate that students' science conceptual understanding significantly improved after the study. Also, the study found that students' actions (representation, analysis, and reflection) were strongly associated with students' achievement in science. Bethke, Wendell, and Rogers (2013) conducted a quantitative study of 592 elementary students to investigate the impact of EDI on students' science achievement compared to the traditional method of teaching science. The curriculum was designed to address four domains of science, including animals, material properties, simple machines, and sound. The results indicated that students' science conceptual understanding significantly improved. The researchers found a significant difference between the impact of EDI in three domains of science (animals, material properties, simple machines) and traditional methods in favor of the EDI. However, the study did not find a significant difference between the two instructional approaches on students' science achievement in the domain of sound. The researcher explained that the material used in the engineering curriculum is suitable to build a wide variety of simple machines but not appropriate for building a sound interment. Thus, the traditional method may become more effective if the material of the engineering curricula is not carefully selected.

Guzey et al. (2017) investigated the impact of EDI on students' science learning and found that the quality of the curriculum is a strong predictor of students' achievements. Also, they indicate that EDI is able to address particular science concepts, stating that there is a "positive impact of engineering on student learning only in physical science, particularly the heat transfer concept" (p. 219). The study argues that curricula developed entirely to integrate engineering design addressed science content more effectively than simply adding engineering activities to an already-existing science unit. Finally, the quality of EDI, which is defined here by its alignment with NGSS and the suitability of the material, is key component for using EDI as a portal to develop students' science conceptual understanding. (Bethke Wendell & Rogers, 2013; Guzey et al., 2017)

High quality EDI greatly influences students' science achievement; however, addressing the underlying science content explicitly to students during the engineering instructional practices positively impacts students' science conceptual understanding. Schnittka and Bell (2011) investigated the impact of EDI compared to the traditional methods in a study of 71 eighth grade students. The participants were divided into three classes. The first class received the traditional instruction, the second class received EDI, and the third class received EDI with an explicit demonstration of the targeted science concepts. The results indicated that students' science achievement significantly increased in all groups; however, students who received EDI with an explicit demonstration of the targeted science concepts significantly outperformed the other two groups. This results may suggest how teachers should facilitate EDI effectively. Addressing the science concepts explicitly during the EDI was emphasized in the *Framework*, too. Apedoe and Schunn (2013) state that, "if we are to use design-based science learning as a pedagogical approach in the science classroom, it needs to be made clear to students what the connections between design and science are" (p. 790). Marulcu and Barnett (2016) investigated the impact of EDI compared to an inquiry-based approach to students’ content learning of simple machines and suggested, "It is possible to use engineering-design as a context for science teaching without sacrificing content learning in a way that engages students in real-life related engineering-design procedures" (p. 102). Finally, engineering design curricula are not equal in terms of highlighting the science phenomena. Also, students may solve the challenge without applying science concepts; therefore, during EDI, teachers are supposed to help students see the connection and apply science concepts to the engineering challenge.

The *Framework* emphasized the importance of providing high-quality science education to all students regardless of their ethnic groups. EDI was found to have a positive impact on students' achievement across different students' groups. Yoon et al. (2014) indicate that EDI has a positive, significant impact on ethnically diverse elementary students' content knowledge. Also, the College of Education and the College of Engineering at the University of Nevada, Reno cooperated with Cantrell et al. (2006) in developing engineering curricula for eighth-grade students. The study indicates that engaging students in EDI diminishes the gap between different ethnic groups in science. In a similar study, Mehalik, Doppelt, and Schuun (2008) conducted a quantitative study to investigate the impact of engineering curricula and scripted inquiry approach. A total of 1,053 students participated in the study. Both curricula share the same learning objectives. The results indicate the engineering curriculum has a significant impact on students' science conceptual understanding, and the engineering curriculum was most helpful to African American students who were not achieving at grade level. Therefore, high-quality engineering curricula and an explicit connection of the science concepts during EDI are supposed to help students' science conceptual understanding regardless of their ethnic groups; in addition, low science achieving students receive benefits as well.

In summary, EDI has the potential for developing students' science conceptual understanding. The issues related to EDI as approaches to improve students’ science conceptual understanding are the alignment to NGSS, the quality of activities material, and the explicit emphasizing of science content during the EDI; however, preparing teachers academically and pedagogically help to minimize these issues.

Summary

In this chapter, the researcher discussed various aspects related to teachers' EDI in developing students’ science conceptual understanding, the influence of teachers’ self-efficacy and beliefs on their instructional practices and how the *Framework* serves as a reference in designing, facilitating, and evaluating EDI. The researcher illustrated how science content is supposed to be integrated into NGSS-aligned engineering instructional design and appears in EDI. Also, this chapter discussed teachers’ PCK with respect to the implementation of NGSS. In this chapter, the researcher attempted to summarize and synthesize the literature in terms of the factors influencing in-service teacher EDI, which include teachers’ preparation and experience. Finally, the researcher discussed the potential of EDI in developing students' science conceptual understanding and the issues related to designing and teaching engineering curricula.

The next chapter discusses the study methodology. It explains the methods used in this study, target population, participants, instruments, type of data, and procedures used to analyze the data.

Chapter 3 - Research Methods

Introduction

The purpose of this study is to investigate the influence of teachers' preparation, teachers' self-efficacy for, and beliefs about, teaching engineering design on science content integration in EDI, and students' science conceptual understanding. To investigate the impact of these three factors, the researcher employed a mixed methods design. Specifically, the researcher used a mixed method convergent design to "collect and analyze two separate databases—quantitative and qualitative—and then merge the two databases for the purpose of comparing or combining the results" (Creswell & Clark, 2017, p. 64). The rationale for using mixed methods is that neither qualitative nor quantitative methods are sufficient to capture the factors influencing the nature of science content integration in EDI and students' science conceptual understanding with sufficient depth and breadth. In this design, the quantitative data help to identify the potential impact of teachers' preparation, self-efficacy for, and beliefs about teaching engineering design. The qualitative analysis complemented the quantitative results. Furthermore, this mixed methods design allows the researcher to compare a sample of what the participants report as they respond to the closed-ended survey items to what they and their students do regarding the integration and application of science content. Finally, this design provides an opportunity for the researcher to compare the qualitative data about the participants, which was gathered by open-ended questions, classroom observations, and document analysis, to the data gathered from a large number of participants via a survey (Creswell & Clark, 2017).

The researcher adopted the parallel-databased design in which the two sets of data are collected and analyzed independently. Then the researcher compared the two sets of results during the interpretation phase. See Figure 3.1.

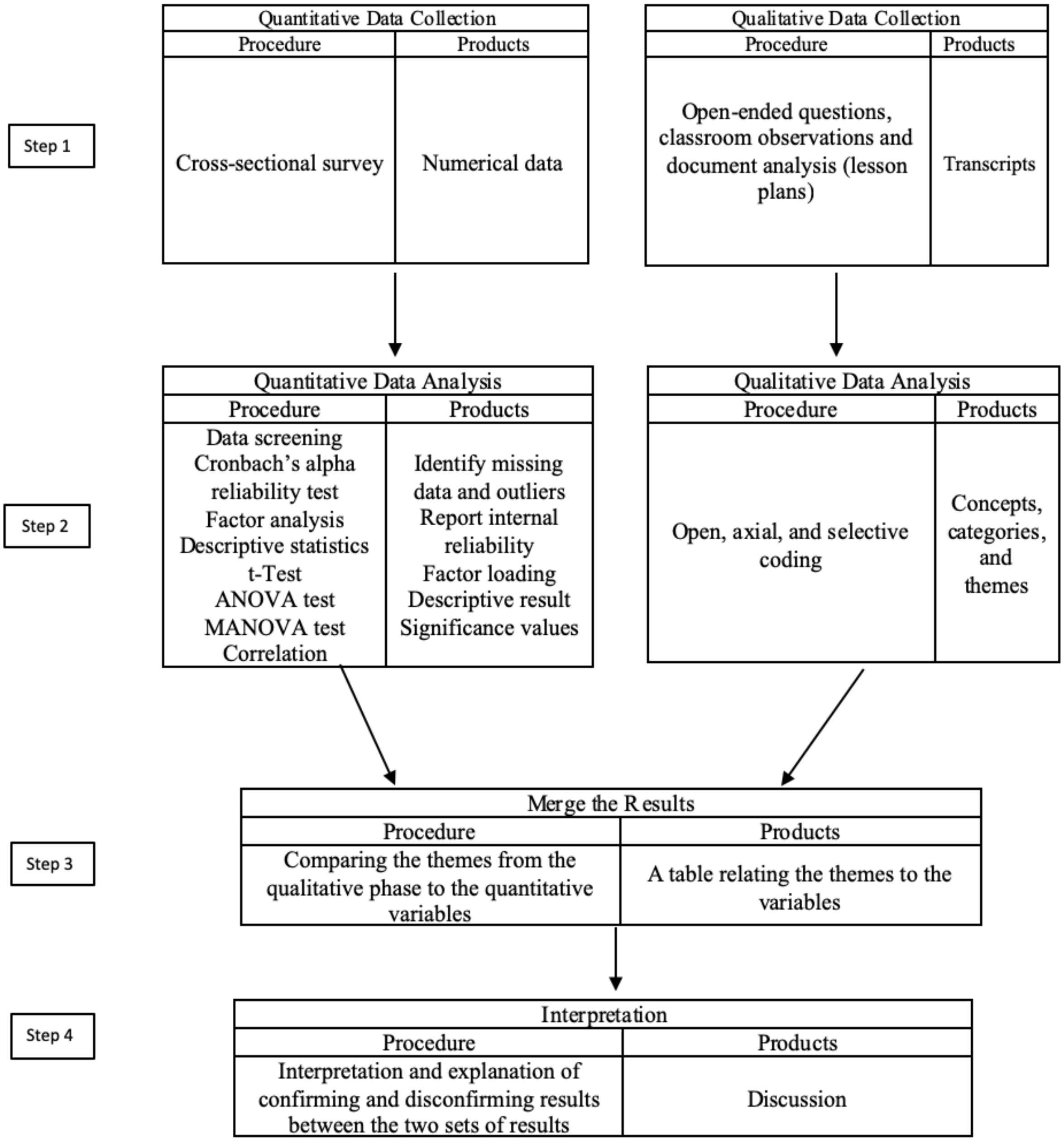


Figure 3.1. Flowchart showing the procedures for this convergent parallel mixed methods design. Adapted from "Designing and Conducting Mixed Methods Research" (p. 70 & 76), by J. W. Creswell and V. L. Plano Clark, 2017, Thousand Oaks, CA: Sage Publications.

Mixed Methods Validity

Combining qualitative and quantitative research designs requires an examination of the validity and the reliability for each design (Creswell, 2014). However, there are several validity threats specifically related to mixed methods design, and it is essential that these threats are taken into consideration. These threats include: not using a parallel concept in the data collection, having unequal quantitative and qualitative sample sizes, keeping the results from different database separate, and failing to resolve disconfirming results (Creswell & Clark, 2017).

The researcher minimized the mixed methods validity threats of not using a parallel concept in the data collection by developing seven open-ended questions to address the same concepts that are discussed in the closed-ended survey items. The study was designed to investigate five concepts: teachers' preparation, self-efficacy, beliefs, science content integration in EDI, and students' science conceptual understanding. Thus, the researcher collected qualitative and quantitative data for each concept.

Another threat to this mixed methods design is having unequal quantitative and qualitative sample sizes. The researcher collected qualitative data using open-ended questions, which were distributed to all participants. The number of the participants who responded to the open-ended questions is reported. Also, the number of the participants who were observed is reported.

Finally, to avoid the issue of keeping the results from different databases separate, the researcher presented the results of qualitative and quantitative data for teachers' academic preparation, professional development, experience, self-efficacy, beliefs, science content integration, and students' science conceptual understanding in a table. This technique, suggested by Creswell (2014), helped reveal the similarities and differences between the two sets of results. After conducting the mixed methods analyses, the researcher resolved issues of disconfirming results analysis by reporting the differences between the results.

Research Questions

This study consists of one qualitative research question, four quantitative research questions, and one mixed-methods research question.

1. (QUAL): What influences elementary in-service teachers’ integration of science content into engineering design instruction and students’ science conceptual understanding?
2. (QUAN): Do elementary in-service teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) influence science content integration in engineering design instruction?
3. (QUAN): Do elementary in-service teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) influence students' science conceptual understanding?
4. (QUAN): Is there a correlation between elementary in-service teachers' self-efficacy for and beliefs about teaching engineering design and science content integration in engineering design instruction?
5. (QUAN): Is there a correlation between elementary in-service teachers' self-efficacy for and beliefs about teaching engineering design and students' science conceptual understanding?
6. (Mixed Methods): Do the qualitative results reveal similar findings of the factors affecting science content integration and students’ science conceptual understanding as the findings of the quantitative analysis?

Qualitative Phase

This qualitative phase seeks to explore the factors affecting science content integration in EDI and student science conceptual understanding by asking the following research question:

What influences elementary in-service teachers' integration of science content into EDI and students' science conceptual understanding?

The researcher collected data from three different sources: open-ended questions, classroom observations, and document analysis, as shown in Table 3.1. Then, the researcher analyzed the data using three analytical procedures suggested by Strauss and Corbin (1998). These analytical procedures include open coding, axial coding, and selective coding.

Table 3.1

The Qualitative Research Question, Data Collection Type, Sampling Procedure, and Data Collection Instrument.

Research question	Data collection types	Sampling procedure	Data collection instrument
What influences elementary in-service teachers' integration of science content into engineering design instruction and students' science conceptual understanding?	Open ended questions	All participants	See questions (4, 16, 18, 31, 37, 45, and 52)
	Classroom observation	Purposeful sampling of 4 participants	EQuIP-OP (Marshall et al., 2010).
	Document analysis	The same observed participants	Lesson plans for the observed classrooms using EQuIP-LP (Achieve, 2016)

Data Sources

The qualitative data include open-ended question responses, classroom observations, and document analysis transcripts. The study was designed to capture teachers' thinking around science content integration in EDI and students' science conceptual understanding through open-ended questions. Also, the integration of science content in EDI as planned (lesson plan) and delivered (lesson observation) was captured through classroom observations and documents analysis. Furthermore, the classroom observation captured students’ science conceptual understanding. Using a combination of qualitative data for analysis serves to increase the validity of findings.

Open-ended questions. A total of seven open-ended questions (see questions 4, 16, 18, 31, 37, 45, and 52 in Appendix A) were developed to measure the same factors suggested in the literature and allowed the participants to provide more data. The reason for using open-ended questions was that this method provided opportunities for all participants to expand their thoughts and provide detailed information about their academic preparation, experience, professional development, science content integration in EDI, students’ science conceptual understanding, and self-efficacy for and beliefs about teaching engineering design, which were analyzed qualitatively.

Observation. The researcher conducted four classroom observations to investigate the integration of science content in the EDI and students’ science conceptual understanding. This approach of collecting data allows the researcher "to observe the activities, people, and physical aspects of the situation" (Spradley, 1980, p. 55) and observe the behavior in real time (Chava & David, 1996). Each classroom observation was scheduled in advance by consulting with the participating teachers. The researcher did not interfere with the instructional process. Observational protocol and field notes were used to record qualitative data and to evaluate the quantity and quality of EDI. The data from the classroom observation allowed the researcher to compare the observed real behavior of facilitating engineering design to the participants’ responses to the open-ended questions. Also, the data provided an opportunity for the researcher to compare the teachers' engineering instructional design (lesson plan) with their EDI.

Electronic Quality of Inquiry Protocol (EQuIP). The researcher used EQuIP-OP (Marshall, Smart, & Horton, 2010) as the observational protocol to record data about the quality of EDI and students' science conceptual understanding (Appendix C). EQuIP-OP consists of four pedagogical constructs that measure the amount and quality of inquiry instruction of science and mathematics classrooms: instruction, discourse, curriculum, and assessment (Marshall et al., 2010). Each construct has five or four factors, and each factor has four levels describing the quality of the observed practice ranging from pre-inquiry (level one) to exemplary inquiry (level four). The researcher chose the instrument in this study because it was found that EQuIP-OP is more effective compared to other published instruments such as The Reformed Teaching Observation Protocol (RTOP) (Marshall, Smart, Lotter, & Sirbu, 2011). EQuIP-OP provides a reliable and valid measurement of the quantity and quality of inquiry that takes place within a lesson (Quigley, Marshall, & Deaton, 2011) .The authors of EQuIP-OP have made it available for use by both teachers and researchers. Because the instrument was developed to measure the quality of inquiry instruction of science and mathematics classrooms, the researcher modified the instrument to ensure it measures the desired concepts, such that the word "activities" was replaced with "engineering design activities" and the word "content" was replaced with "science content." Please refer to Appendix C for all modified words that were highlighted.

Field notes. Field notes were taken during the observations, providing a detailed description of what the researcher observed during the EDI. The field notes were used along with the EQuIP-OP to include a description of the interactions between the teacher and the students, a description of the classroom setting, and a description of the interactions between the students themselves. After each classroom observation, the researcher took reflective field notes, as recommended by Creswell (2014). The reflective field notes include a description of the researcher's reaction to the observed classroom, and thoughts, ideas, or questions that emerged during the observation.

Document analysis. The researcher collected four lesson plans developed by the participants who were observed in this study. According to Bowen (2009), document analysis refers to a systematic technique for reviewing a document and is used as a means of translation. The lesson plan contains information that helped the researcher verify a finding (Bowen, 2009). There are several advantages to including document analysis, such as efficiency, availability, cost-effectiveness, lack of reactivity, and coverage (Bowen, 2009). In this study, the researcher collected and analyzed teachers' engineering design lesson plans, which helped to examine how the participants intended to integrate science content in EDI. Analyzing the lesson plan had several benefits. For example, these lesson plans were expected to be less affected by the research process. Also, the lesson plans were expected to contain the learning objectives developed by the teachers, which helped the researcher examine how the science content was integrated in EDI.

Educators Evaluating the Quality of Instructional Products (EQuIP). The researcher used a modified version of EQuIP-LP Version 3.0 (Achieve, 2016) as a rubric to evaluate and analyze the alignment of the lesson plans to the NGSS. The rubric was originally developed to provide criteria for measuring the quality of units and lessons to be aligned with the NGSS to review lessons plans to determine what revision is needed and to produce feedback on ways that instructional materials can be improved. Therefore, the researcher used the EQuIP-LP as a tool to investigate the teachers’ intention to integrate science content in EDIs and monitor students’ science conceptual understanding.

The EQuIP-LP rubric contains three categories: NGSS three-dimension design, NGSS instructional supports, and monitoring NGSS students’ progress. The researcher evaluated the lesson based on the criteria that was developed to evaluate engineering design lessons in each category. Any criteria that were included in the original rubric and developed to evaluate units was not used in this study.

In Category I of the EQuIP-LP rubric, NGSS three dimensions design were evaluated based on three criteria. In Section A, the lesson was evaluated regarding whether the lesson allows the student to design a solution, and whether the engineering design lesson was integrated to develop DCIs from physical, life, and/or earth and space sciences. In Section B, three dimension, the engineering design lesson plans were evaluated based on whether the lesson was designed to provide an opportunity to develop and use specific elements of SEPs, DCIs, and CCCs during the EDI. In Section C, integrating the three dimensions, the lesson was evaluated as to whether the students’ solution to the engineering problem require students to integrate SEPs, DCIs, and CCCs.

In Category II: NGSS Instructional Supports of the EQuIP-LP, the lesson is evaluated as to whether the lesson plans include evidence of relevance and authenticity, student ideas, building progression, scientific accuracy, and differentiated instruction. In Section A, relevance and authenticity, the criteria evaluated whether students engage the engineering problem as directly as possible. This also evaluates whether the lesson includes suggestions for how to connect EDIs to students’ homes, neighborhood community, and/or culture as appropriate. Also, Section A evaluates whether the lesson provides an opportunity for students to connect their engineering design solution to questions from their own experience. Section B, Student Ideas, allows the researcher to investigate whether the lesson plan is designed to provide an opportunity for students to express their science conceptual understanding during the EDI. Specifically, Section B allows the researcher to report any specific evidence from the lesson plan that indicates whether students are given the opportunity to express, clarify, justify, interpret, and represent their idea and respond to peer and teacher feedback orally and/or in written format during the EDI. In Section C, Building Progressions, the researcher used these criteria to investigate whether the lesson clearly addresses how the prior learning will be built upon. In Section D, Scientific Accuracy, the lesson was evaluated in terms of accuracy of scientific information to support student three-dimensional learning during EDIs. In Section E, Differentiated Instruction, the lesson was evaluated based on whether the lesson provides appropriate reading, writing, listening and/or speaking alternatives for students who are English language learners, have special needs, or read below the grade level. Also, this section includes criteria to investigate whether the lesson includes extra support for students who are struggling to meet the target expectations and extensions for students who have already met the performance expectation to develop a deeper understanding of SEPs, DCIs, and CCCs.

In Category III: Monitoring NGSS Student Progress of the EQuIP-LP, the researcher used the criteria of this category to evaluate whether the lesson includes clear and compelling evidence of monitoring three-dimensional students’ performance, formative, scoring guidance, and unbiased tasks/items. Specifically, this category helped the researcher to investigate how and when teachers are planning to measure the students’ science conceptual understanding. In Section A, Monitoring Three-Dimensional Students’ Performance, the criteria investigate whether the lesson allows monitoring of student performance in the three-dimensional learning.

The researcher used these criteria to investigate how the teachers intend to monitor the students' performance expectation related to DCIs. In Section B, Formative, the researcher used these criteria to investigate how the formative assessment is imbedded throughout the lesson. In Section C, Scoring Guidance, the criteria are used to evaluate whether the rubric for student performance provides guidance for interpreting students' performance in the three dimensions. In Section D, Unbiased Task/Items, these criteria allow the researcher to investigate whether the methods, vocabulary, representation, and examples that are used to assess students' proficiency are unbiased and accessible for all students.

Furthermore, all categories in the rubric include a section that allows the reviewer to provide suggestions for improvement and evaluate lessons using the rating scale range from 0 (no evidence for meeting any criteria in the category) to 3 (extensive evidence to meet at least two criteria in the category). The rubric was made available for educators' use.

Validity and Reliability

Terms used by various authors for qualitative validity include trustworthiness, authenticity, or credibility (Creswell, 2014). Qualitative validity "means assessing whether the information obtained through the qualitative data collection is accurate" (p. 217). Several strategies are typically used to ensure the validity of qualitative research, such as the triangulation of data and reporting disconfirming evidence. The researcher followed these strategies to ensure the trustworthiness of the study.

Qualitative reliability refers to the consistency across different researchers and projects (Creswell, 2014). For this study, the researcher used the following procedures to check the reliability of the study: check the transcripts to make sure the transcripts are free of errors, and constantly compare the data with the code by writing memos about the codes and their definitions.

Procedures

After receiving approval from the Institutional Review Board (IRB), the researcher distributed the survey through email (see Appendix D). The participants received information about the purpose of the study, IRB approval, and a hyperlink to the survey. Also, the participants were informed that it should take approximately 12 minutes to complete the survey. The survey included a question asking the participant to be observed. A follow-up email was sent to the participants who agreed. Written consents were obtained before classroom observations were conducted. Consent forms were signed by principals, teachers, students, and the parents of the students.

Qualitative Data Analysis

Preparing and organizing the data. Transferring the responses of the participants of the open-ended question to NVivo software was the first step toward analyzing the qualitative data. The researcher organized the data to be categorized by the open-ended questions. Thus, the participants that responded to the open-ended questions were divided into seven categories. Each category addressed one open-ended question. The researcher read the transcript several times to begin the analyzing process. As Kim (2016) emphasized, in general, analyzing qualitative research data should follow four steps: coding, categorizing, identifying patterns, and creating themes.

At the end of each week, the researcher typed the handwritten field notes of the classroom observation in a Microsoft Word document, and reviewed the notes to expand and clarify them before starting the coding procedure. Each document includes the researcher’s evaluation of the EDI using the rubric (Marshall et al., 2010), descriptive information, and reflective thoughts.

The researcher collected a lesson plan from each observed participant, and investigated and analyzed each lesson plan using the digital version rubric (Achieve, 2016). The researcher reviewed each lesson plan and the observation evaluations to ensure accuracy in data recorded. The final version of the transcript includes descriptive information about the lesson, the teacher's demographical information, and an evaluation of science content integration.

Coding procedure. The researcher analyzed the qualitative data to answer the first research question. There were two analytic tools suggested by Strass and Corbin (1998) that were necessary to facilitate the coding process. These tools include making comparisons and asking questions. The first tool consists of making comparisons between participants' EDIs to determine similarities or differences in terms of integrating science content during EDI. The field notes that were collected during different classroom observations were compared to each other to investigate how the participants are different or similar in terms of integrating science content during EDI. Also, the researcher compared each participant's response to the open-ended questions with the field notes collected during the classroom observation. The second tool consists of the researcher asking questions during the analysis phase. The researcher asks sensitive, theoretical, and practical questions (Strass & Corbin, 1998). Asking these types of questions helped the researcher's understanding of what teachers' responses to the open-ended question might indicate and helped to identify initial issues that might need to be addressed, make connections among concepts, and see the variation in the data (Strass & Corbin, 1998).

The researcher started the first practical phase of analysis procedure by conducting open coding, which refers to "a preliminary process of breaking down, examining, comparing, conceptualizing and categorizing data" (Strass & Corbin, 1998, p. 60). During this phase of coding, the researcher labeled all concepts found in all three types of data. Also, the researcher reduced the number of concepts by categorizing the labeled concepts into different categories, and each category was developed based on its properties and dimensions.

The researcher continued the analysis by conducting Axial coding, which refers to "a set of procedures whereby data are put back together in new ways after open coding, by making the connection between categories" (Strass & Corbin, 1998, p. 96). The researcher linked the sub-categories to their categories, which would provide a complete picture of the phenomena. Also, during this phase of analyzing the data, the researcher searched in the data to link the major categories together. By the end of this phase, the researcher identified conditions, actions, and consequences related to science content integration and students' science conceptual understanding (Strass & Corbin, 1998). Selective coding, which refers to "the process of integrating and refining the theory" (p. 161), was the final phase of analyzing the data. The researcher organized the major categories around a central concept, and used a diagram to facilitate the process.

Finally, the researcher collected qualitative data from three different sources: open-ended questions, classroom observations, and documents analysis. The process of analyzing the qualitative data was not linear. The researcher analyzed the data collected by the open-ended questions, and the emerging findings guided the selection process of participant data. This cyclical process continued until the researcher had reached the satisfactory conceptual model.

Themes. All three types of coding were employed to help the researcher identify the emerging themes related to the first research question. According to Saldaña (2013), "A theme is an outcome of coding, categorization, or analytic reflection” (p. 14). The emerging themes were reported as the findings of the study.

Quantitative Phase

This part of the study employed a cross-sectional survey that "provide[s] a ‘snapshot’ of the outcome and the characteristics associated with it, at a specific point in time" (Levin, 2006, p. 24). This survey design, which was conducted through Qualtrics to gather data, provided an opportunity for the researcher to collect and analyze data from a representative sample of a large population of elementary teachers. Other benefits of using survey design include the efficiency of survey design; the ease of analyzing the data; and that survey design allows the researcher to discover if there is a relationship between variables, particularly after collecting data from a large sample.

Participants

The target population was elementary in-service teachers from all 891 elementary schools in the state of Kansas who are currently teaching science as a part of their daily curriculum. To ensure representative sampling, the researcher planned to reach the entire population of teachers using the following techniques. First, the researcher generated a list of all 286 public school districts and 38 private school districts in Kansas. The list included the name of the district and the county, which were collected from the Kansas State Department of Education website. The researcher randomly selected a school district from each county in Kansas. A link to the survey was sent to all elementary teachers in each selected school district. This technique of including a school district from each county may minimize the potential impact of coverage errors, which usually "occurs when the list from which sample members are drawn does not accurately represent the population on the characteristics" (Dillman, Smyth, & Christian, 2014, p. 3). To increase the response rate, a follow-up email was sent out seven days after the first invitation letter for the survey. Two hundred and twenty-two participants from 70 counties completed the survey resulting in a 3.9% response rate. (see Figure 3.2).

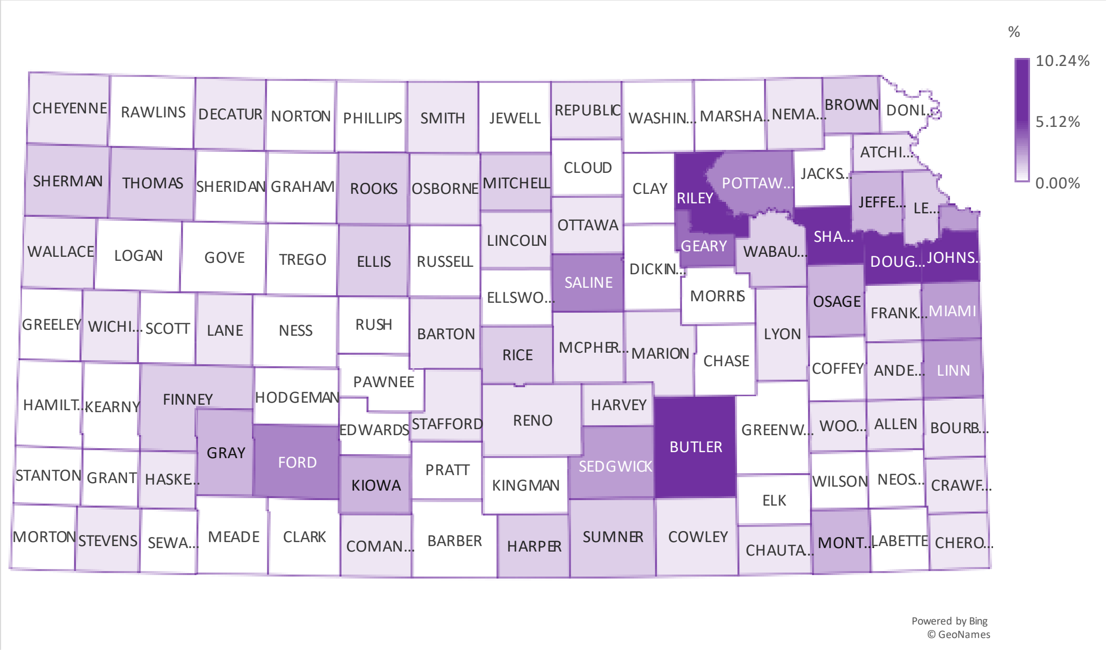


Figure 3.2. The demographic locations of the participants.

Measurements

This study investigated the impact of teachers' preparations, self-efficacy for, and beliefs about teaching EDI on science content integration in EDI and students' science conceptual understanding using a modified survey. The survey was developed by combining and modifying several instruments that were developed by a team of scholars to answer the four quantitative research questions (see Table 3.2). The following section provides details about the instruments.

Demographic data. The instrument includes demographic data such as gender, ethnicity, school Title I eligibility, teaching experience, science teaching experience, grade level taught, and the frequency of teaching engineering design. The collected data provided descriptive information about the sample. Also, the researcher used the data to determine if demographical variables had an impact on the dependent variables.

Teachers' preparation. To investigate teachers' preparation, the researcher selected items from the 2012 National Survey of Science and Mathematics Education, which was developed by Banilower et al. (2013)**,** with support from the National Science Foundation (NSF), to identify trends in science and mathematics education. The researcher chose items from the survey to collect data about teachers' academic preparation, degree level, professional development, and the number of years teaching engineering design. The following sections present a description of the specific measurements and their operationalized items related to teachers' preparation.

Teachers' academic preparation. This part of the survey is designed in a logical sequence by guiding the participants based on their previous response. For example, the participants were asked questions such as, "Have you been awarded one or more bachelor's and/or graduate degrees in the following fields?" The participants who chose "a. Education, including science education" were asked, "What type of education degree do you have?" and the presented options were related to education degrees, such as "Elementary Education," "Mathematics Education," and "Science Education." When the participants chose, for example, "b. Natural Sciences and/or Engineering" a different question was presented to them, which was "What type of natural science and/or engineering degree do you have?" This strategy of investigating teachers' academic preparation minimized the time and effort by the participants to complete the survey. A total number of 10 items divided the participants into three groups as follows:

1. Participants with a degree in education: The participants were identified by their response to questions 5 and 6.
2. Participants with a degree in education plus advanced courses in science: The participant were identified by their response to questions 5, 6, 8, 9, 10, 11, and 12
3. Participants with an undergraduate or graduate degree who have taken engineering design courses: This group of participants were identified by their response to questions 13 and 14.

Degree level. The survey included questions asking the participants about their highest degree level (Question 15). This question divided the participants into three groups (bachelor's degree, master's degree, doctoral degree).

Professional development. The researcher adapted question 17 to measure the impact of professional development on the dependent variables. The original item was developed by Banilower et al. (2013) to measure professional development related to science. However, the researcher modified the question to focus on professional development related to engineering design. Also, the researcher added a response option to identify the participants who had never attended professional development devoted to engineering design. The question categorized the participants into five groups: never attended professional development workshops, spent less than six hours in workshops, spent a range of 6 - 15 hours in workshops, spent a range of 16 - 35 hours in workshops, and spent more than 35 hours in workshops. This question allows the researcher to investigate if the amount of time spent in professional development influences science content integration in EDIs and students' science conceptual understanding.

Years of teaching engineering design. The researcher adapted a question (Question 1) to measure teachers' years of experience in teaching engineering design. The question was

Table 3.2

Research Questions, Variables Names, Instruments, and Items in the Survey

	Independent variables			Dependent variables		
Research question	Variable name	Instrument	Items in the survey	Variable name	Instrument	Items in the survey
Do elementary in-service teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) influence science content integration in engineering design instruction?	Academic preparation	Banilower et al. (2013)	5-14 (10 items)	Science content integration	Hayes et al, (2016)	38-44 (7 items)
	Degree level	Developed by the researcher	15			
	Professional development	Banilower et al. (2013)	17			
	Engineering design teaching experience	Banilower et al. (2013)	1 (c)			
Do elementary in-service teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) influence students' science conceptual understanding?	Academic preparation	Banilower et al. (2013)	5-14 (10 items)	Students' science conceptual understanding	Hayes et al, (2016) Friday Institute for Educational Innovation, (2012)	46-49 (4 items) 50-51 (2 items)
	Degree level	Developed by the researcher	15			
	Professional development	Banilower et al. (2013)	17			
	Engineering design teaching experience	Banilower et al. (2013)	1 (c)			
Is there a correlation between elementary in-service teachers' self-efficacy for and beliefs about teaching engineering design and science content integration in engineering design instruction?	Self-efficacy for teaching engineering design	BSEEE-T	32-36 (5 items)	Science content integration	Hayes et al., (2016)	38-44 (7 items)
	Beliefs about teaching engineering design	BSEEE-T	24-30 (7 items)			
Is there a correlation between elementary in-service teachers' self-efficacy for and beliefs about teaching engineering design and students' science conceptual understanding?	Self-efficacy for teaching engineering design	BSEEE-T	32-36 (5 items)	Students' science conceptual understanding	Hayes et al., (2016) Friday Institute for Educational Innovation, (2012)	46-49 (4 items) 50-51 (2 items)
	Beliefs about teaching engineering design	BSEEE-T	24-30 (7 items)			

originally developed by Banilower et al. (2013) to measure teachers’ years of experience in teaching in general, and teachers’ years of experience in teaching science. The researcher added Item C to measure the years of experience in teaching engineering design (see Question 1). The experience was measured by the number of years the participants have taught engineering design at the beginning of the study.

Self-efficacy for teaching engineering design. Investigating science teachers' self-efficacy started when Riggs and Enochs (1990) developed the Science Teaching Efficacy Belief Instrument (STEBI-A), which has been widely used in science education for in-service teachers. Several validated instruments, such as Friday Institute for Educational Innovation (2012) and Engineering Design Self-Efficacy Instrument (EDSI) developed by Carberry, Lee, and Ohland (2010), were developed previously to measure teaching engineering self-efficacy. Recently, Rich, Jones, Shumway, and Anderson (2018) developed an instrument to measure Teachers' Beliefs and Self-Efficacy in Elementary Engineering (BSEEE-T) with a goal of developing a short, validated survey that takes teachers 10 minutes to complete. The researcher chose this most recent instrument in this study for four reasons. First, this instrument reduces the total number of questions of the initial survey from 73 to 56 items. Second, the instrument was developed to measure two variables, which are self-efficacy and beliefs about teaching engineering design. Third, this instrument can be used in this study without any modification that may affect the validity. Fourth, the validity and reliability are above the acceptable level. Cronbach’s alpha reliability coefficient for self-efficacy is .85. The instrument contains five items to measure teacher self-efficacy (See questions 32 to 36), such as “I believe that I have the requisite science skills to integrate engineering content into my class lessons,” and “I can create engineering activities at the appropriate level for my students.” A 6-point Likert-type scale was used (1 = strongly disagree, progressing to 6 = strongly agree). The average score of each participant was calculated to reveal the degree of teacher self-efficacy for teaching engineering design.

Beliefs about teaching engineering design. How teachers value subject matter influences their motivation and effort in teaching. Therefore, the researcher included in this study teachers' beliefs about engineering design. The researcher used the same instrument developed by Rich, Jones, Shumway, and Anderson, (2018) that was discussed previously to measure teacher beliefs about teaching engineering in elementary school. The instrument includes seven items such as, “Providing more in-class engineering activities would enrich the overall learning of my students;” and “Engineering concepts should be taught much more frequently in elementary school.” The five items were measured on a 6-point Likert-type scale (1 = strongly disagree, progressing to 6 = strongly agree.) Cronbach’s alpha reliability coefficient for this construct was .92. Teachers’ beliefs about teaching engineering design were measured using seven questions (24-30) and calculating the average score of each participant.

Science content integration. Due to the paucity of research-based instruments designed to measure science content integration in EDI in-depth, the researcher modified the Science Instructional Practices (SIPS) (Hayes, Lee, DiStefano, O’Connor, & Seitz 2016). This instrument measures science instructional practices that align with the NGSS. The 31-item survey contains six subscales: (a) instigating an investigation, (b) data collection and analysis, (c) critique, explanation, and argumentation, (d) modeling, (e) traditional instruction, and (f) prior knowledge. Cronbach’s alpha for the six factors ranged from .80 to .88. The process of modifying the survey began by selecting all items that were originally developed to measure science content integration in EDI from the six subscales of the survey. Seven items were explicitly designed to measure teachers' actions in integrating science content in EDI. For example, the participant responded to questions such as, "How often do you do each of the following in your engineering design instruction" with options such as, "Go over science vocabulary;" and "Apply science concepts to explain natural events or real-world situations." The selected items were reviewed by a content expert in science education to ensure the items were designed to measure science content integration. The final modified instrument contains seven items selected from the original survey (see questions 38-44). A 5-point Likert-type scale was used (ranging from 1 = never, to 5 = daily or almost daily). The validity and reliability is discussed in chapter 4.

Students' science conceptual understanding. The instrument designed to measure students' science conceptual understanding is a combination of items from two different instruments. Four items (questions 46-49) were adapted from an instrument developed by Hayes, Lee, DiStefano, O'Connor, and Seitz (2016)**,** and two items (questions 50-51) were chosen from Friday Institute for Educational Innovation (2012) for a total of six items. These items were originally designed to measure the students' actions as they discussed and applied science during EDI, as reported by the teacher. For example, the participant responded to questions such as, "How often do your students create a physical model of a scientific phenomenon (like creating a representation of the solar system)?" A 5-point Likert-type scale was used (ranging from 1 = never, to 5 = daily or almost daily). The average score was calculated. The validity and reliability is discussed in chapter 4.

Quantitative Data Analysis

The quantitative analysis process began by transferring the data from Qualtrics survey software to the Statistical Package for the Social Sciences (SPSS) version 25. The researcher screened, revised, and prepared the data to be statistically analyzed using SPSS. Any missing data or outlying information were eliminated from the statistical analysis.

Variable descriptions. The data was expected to contain errors, missing data, and outliers that influence the results; therefore, the researcher started the analysis by conducting a descriptive analysis for each variable. Examining the minimum, maximum, and average score of each item helped identify any errors in the data. Also, the researcher reported the descriptive results about the participants' demographic information and barriers to teaching engineering design.

Measurement reliability. Before conducting any statistical analyses, the internal consistency was measured using Cronbach's alpha, which is the most widely used test for exploring the internal reliability of the scale (Tavakol & Dennick, 2011). According to Tavakol and Dennick (2011), Cronbach's alpha test score "describes the extent to which all the items in a test measure the same concept or construct" (p. 53). The score can range between 0 and 1. The minimum acceptable score for Cronbach's alpha is .7 (Tavakol & Dennick, 2011). A low number of questions, poor interrelatedness between items, or different constructs could produce a low alpha value (Tavakol & Dennick, 2011). Also, a high alpha value could be due to having redundant items (Tavakol & Dennick, 2011). Therefore, the researcher planned to eliminate items with a very low correlation or a very high correlation for the items that measure the dependent variables.

Factor analysis. Factor analysis is a widely used process to investigate the validity of the scale (George & Mallery, 2011). The researcher conducted the factor analysis to measure the validity of the instrument that measures the integration of science content in EDI and students' science conceptual understandings. The researcher selected four items from the original instrument and added two items from a different instrument, using factor analysis as necessary to check the scale validity and eliminate unrelated items.

Independent t-test. To investigate the influence of participants' gender and school Title I eligibility on science content integration and student science conceptual understanding, the researcher conducted an independent t-test.

One Way Analysis of Variance (ANOVA). The researcher used an ANOVA test to investigate whether the ethnicity of the participants had a significant impact on science content integration in EDI and students' science conceptual understanding.

MANOVA. According to Weinfurt (1995), MANOVA is used to measure "the statistical significance of the effect of 1 or more independent variables on a set of 2 or more dependent variables" (p. 245). The researcher chose this test to answer the second and third questions. MANOVA test was used to investigate the impact of teachers' preparation on science content integration in EDI and students' science conceptual understanding. This test was chosen because each independent variable included in the research question categorizes the participant into more than two groups. Also, the study includes two related dependent variables. Finally, including the two dependent variables in one test would reduce the chance of a Type I error occurring compared to conducting ANOVA tests.

Correlation. A correlation test was used to measure the relationship between the investigated variables. The investigated variables include self-efficacy, beliefs, science content integration, and students' science conceptual understanding. The researcher chose this test to answer the fourth and fifth research questions. To answer the fourth research question, the researcher conducted two correlation tests. The first test was to investigate the relationship between participants' self-efficacy scores and the score of the participants' science content integration. The second test was to investigate the relationship between participants’ beliefs scores and the score of the participants' science content integration. Also, the fifth research question was answered using the two sets of scores (participants' self-efficacy scores and participants’ beliefs scores) and the score of students’ science conceptual understanding.

Mixed Methods Analysis

To answer the mixed methods research question (the sixth research question), the researcher analyzed the data by comparing the two separate results of the quantitative and qualitative databases. This procedure consists of three steps: finding shared concepts, developing a table to compare the results, and interpreting the results as follows.

After obtaining the results by analyzing the qualitative and quantitative data, the researcher looked for shared concepts across the two sets of findings related to teachers’ preparation, self-efficacy, beliefs, science content integration in EDI, and students’ science conceptual understanding. (Here, “concept” refers the qualitative themes and quantitative variables). A table was developed to compare the qualitative and quantitative data. The comparison of the results helped the researcher to confirm or disconfirm a relationship between the data sets. In what ways the two sets of results confirm or disconfirm each other were presented using a table. Also, the researcher conducted further analysis of the two data sets to provide advanced interpretation of why the two sets of data confirm or disconfirm.

Finally, conducting a mixed methods analysis reveals factors that influence teachers’ integrations of science content and students’ science conceptual understanding from the data collected by the survey and supportive evidence from the qualitative data to provide more credibility and explanations of the data.

Summary

This chapter covered the study methodology including the study design, the validity of mixed methods design, research questions, the qualitative phase and the quantitative phase. The qualitative phase included data source, validity, reliability, procedure, and qualitative data analysis while the quantitative phase included the participants, measurements, and quantitative data analysis.

After collecting and analyzing the data, the researcher will report the findings of qualitative and quantitative data in the next chapter. The researcher will report findings that relate to the process of screening and investigating the quantitative data, including the results of internal reliability, factors analysis, independent t-test, ANOVA, MANOVA and correlation. Also, the researcher will report the findings of combining the two sets of data, including the similarities and differences between the qualitative and quantitative results.

Chapter 4 - Findings

The purpose of this study was to investigate the effects of teachers' preparation, self-efficacy for, and beliefs about teaching engineering design on science content integration and students' science conceptual understanding during EDI. In this mixed-methods study, a cross-sectional survey, open-ended questions, classroom observations, and documents analysis were used to investigate the factors that influence science content integration and students' science conceptual understanding. This chapter presents the results of the qualitative, quantitative, and mixed-methods data analyses according to the research questions outlined in the study.

Qualitative Data Analysis

Research Question One

What influences elementary in-service teachers' integration of science content into engineering design instruction and students' science conceptual understanding?

To answer this research question, the researcher distributed seven open-ended questions, conducted four classroom observations, and collected four lesson plans developed by the observed participants. This section presents a detailed analysis of each type of data.

Analysis of Open-Ended Questions

The researcher developed the open-ended questions to collect qualitative data about participants' experience and academic preparation, professional development, self-efficacy for and beliefs about, teaching engineering design, science content integration, and students' science conceptual understanding (see Table 4.1). What follows are the results of each open-ended question.

Table 4.1

A list of the seven open-ended questions included in the survey and the number of respondents (N)

Domain (D)	Open-ended question	N
Teaching experience	1. Please describe how your past teaching experience has influenced or not influenced your engineering design instruction.	210
Academic preparation	2. In your own words, explain if your undergraduate and/or graduate studies prepared or did not prepare you to teach engineering design.	241
Professional development.	3. Please describe how your professional development did or did not affect your engineering design instruction.	172
Belief about teaching engineering design	4. What were your initial views/feelings about the inclusion of engineering design in the NGSS for grade K-6?	168
Self-efficacy of teaching engineering design	5. Please describe how prepared or unprepared do you feel to teach engineering design.	142
Engineering design and science content	6. Please describe how science content is integrated during your engineering design instruction.	106
Engineering design and students' science conceptual understanding	7. Please explain how effective or ineffective you find engineering design to teach science content for your students.	88

Teaching experience (D1). Participants were asked to provide descriptive responses to the question, "Please describe how your past teaching experience has influenced or not influenced your engineering design instruction." Their responses indicate that their experience ranged from "never taught engineering design" to "have extensive teaching experience." The analysis of participants' responses reveals the levels of EDI implementation and obstacles associated with pre-implementation and novice experience levels (see Figure 4.1).

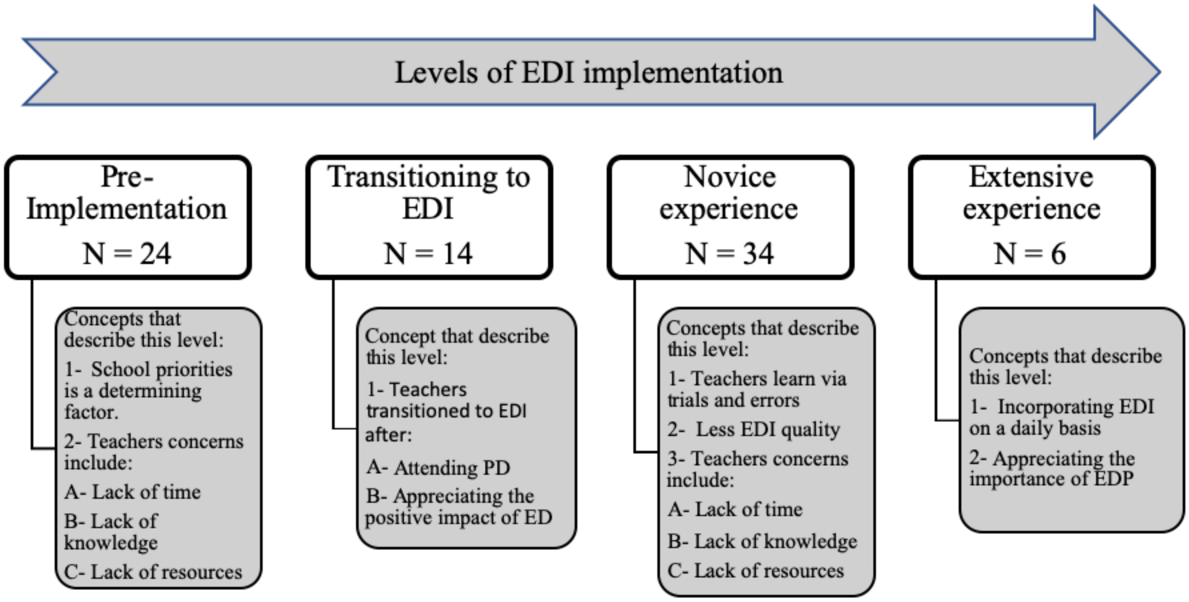


Figure 4.1. Level of EDI implementation.

Level of EDI implementation. Following analysis of responses, there were 78 participants whose comments specifically revealed four levels of EDI implementation, which are pre-implementation, transitioning to EDI, novice experience, and extensive experience. Also, participants provided descriptive details about each level of EDI implementation.

Pre-implementation. Twenty-four participants reported that they had never taught EDI. A participant stated, "I have had no experience." Participants tend to refer to a single reason preventing them from integrating EDI in their classroom: school priority. School priority is a concept that refers to the decision made by the school or at the district level that determines the degree to which engineering design is adopted in the school. School priority determines teachers' teaching assignments, priorities, and accessibility to resources and knowledge needed to teach engineering design. Participants usually did not start implementing engineering design until it was officially implemented by the school or district. As a participant stated, “I didn't teach engineering design until it was included in a new curriculum I started using,” while another participant indicated that engineering design is one of her school priorities. She stated, “My school is a STEAM signature school, so engineering design instruction is important throughout our building.” This suggests that teachers would not have the experience of teaching engineering design if it were not prioritized by the school.

Furthermore, participants reported that they did not teach engineering design because they did not know how to teach it. They indicated that they need training or professional development to integrate EDI in their classrooms. A participant stated, “I have received no professional development in this area, so I don't feel I do it well at all.” Another participant indicated that, “Our curriculum does not incorporate engineering design. I am hoping our school [will] adopt or start incorporating it/providing teacher training.” These comments support the conclusion that school priority shapes teachers’ experience in teaching engineering design.

Transitioning to EDI. Participants transitioned to begin implementing engineering design after they learned about it and appreciated the potential positive impact of engineering design on their students. Some participants indicated that after attending professional development workshops about teaching engineering design they started teaching it. A participant stated, “Attending conferences and science labs at the Greenbush Education Center makes me want to teach more engineering design. They have such great ideas and resources.” In addition, participants emphasized that they found that EDI helped students with knowledge retention, communicating skills, reasoning, and creativity. A participant stated:

> I began researching ways to incorporate this into my teaching and ran across STEAM. I began using it and have seen a huge benefit--not only for my kids’ “engineering skills,”

> but also their soft skills. Perseverance, communication, and creativity are just some of the areas that are naturally covered with this type of teaching.

Furthermore, 11 participants revealed that students’ excitement about engineering design is the driving factor encouraging them to transition to EDI. A participant stated, "I have found in the past few years teaching, students get really excited to learn about engineering design. This has encouraged me to continue teaching it to all of my students.” To conclude, teachers at this level transition to EDI when they learned about it and become aware of the potential positive impact of EDI on their students.

Novice experience. Teachers with novice experience described how they teach engineering design. “Trial and error” is a common response among participants to describe the struggle and the progress they experienced when they began teaching engineering design. A participant stated, "So much of the engineering design process is trying out a method, making adjustments, and then trying it again.” Participants become more aware of the time needed for the instruction and the right group size. A participant stated, "Through my past teaching experience I have learned through trial and error of what works and what doesn't; that students usually need more time than at first thought; and that smaller groups of 3-4 tend to work better.”

Also, the descriptive responses of novice teachers reveal the quality of their EDI. One finding is that some teachers with novice experience did not integrate engineering design in their instruction. A participant stated, "One of our units is about simple machines, so we talk a bit about engineering in that unit.” This suggests that during the lesson, teachers with novice experience talk about engineering without the implementation of engineering practices as suggested in the *Framework.* Another participant stated, “I am not a science teacher, but during my social studies unit on Rome we talk about engineering and the use of the arch, dome, and vaulted ceilings." Such comments suggest that teachers with novice experience may not implement engineering design in their classroom as outlined in the *Framework*.

Extensive experience. Participants with extensive experience indicated that their experience helped them focus more on incorporating EDI in their curriculum. A participant stated, “My instruction has evolved over the past 10 years. As STEM/STEAM has become more forefront in the curriculum, I've focused more and more on it each year and incorporating ‘construction and engineering’ into my daily routine.” Another point discussed by experienced teachers is the focus on EDP. A participant stated, “I can see how it is vital for ALL ages to receive Engineering Design Process instruction and have made it a priority in my STEM classroom.” In addition, extensive experience in teaching engineering design helps teachers shift their instruction to be student-centered. A participant stated, “My past teaching experience has influenced me by [helping me realize] the kids need to figure out the problem on their own. That is why I enjoy teaching STEM. The kids have to figure out the problem on their own.” Another participant confirmed this idea by stating, “My past experience has encouraged me to let my students be more creative and think on their own rather than following a given plan.” Extensive experience of integration EDI encourages teachers to value and incorporate EDP and shift the instruction to be student-centered.

Obstacles for pre-implementation and novice experience. This concept refers to the difficulties that prevented teachers from implementing engineering design in their classrooms. These obstacles were more likely to be discussed by participants who have never taught engineering design or teach engineering design only a few times a year. Participants reported that the lack of time, knowledge, and resources were the main obstacles limiting their ability to implement engineering design in their classrooms.

Lack of time. Twelve participants indicated that they do not have time to integrate engineering design in their instruction. A participant stated, “It is tricky to find the time.” Many reported that they have a busy schedule. Another participant stated, “Usually just not enough time in the day for science/engineering.” In addition, teachers who teach at primary grades tended to report that the lack of time was the main obstacle that prevented them from teaching science. A participant indicated, “Current curriculum and the stressed importance of reading and math at the lower levels makes the inclusion of sciences difficult.” Another issue discussed by several participants is that EDI is an instruction that takes a long time compared to traditional science instruction. A participant stated, “Projects are usually too long.” To conclude, teachers’ busy schedules, schools’ priority of teaching reading and math to lower grade students, and the complex nature of EDI lead to a lack of time for teachers, which prevents them from integrating engineering design in the classroom.

Lack of knowledge. This concept refers to the lack of sufficient knowledge teachers need to teach engineering design. Participants reported that they need professional development to learn about engineering design to effectively implement engineering design in their classrooms. As a participant stated, “I have received no professional development in this area, so I don't feel I do it well at all.” This issue was prevalent among participants who had never taught engineering design, which may suggest that they never taught engineering design because they did not know how to teach it. As a participant stated, “I don't know how to do it.” In addition, the lack of knowledge seems to reduce the frequency of teaching engineering design. As a participant stated, “I have not had a lot of training in this area, so I do not do this a lot in my classroom.” Another participant stated, “I would like to teach more but do not feel like I have had enough training opportunities, especially locally.” These comments indicate that the lack of knowledge is a common factor among participants that limits their ability to integrate engineering design in their classrooms.

Lack of resources. This concept refers to the lack of materials, ideas, or curriculum needed to implement EDI. Participants indicated they did not have the time to search or prepare for EDI. A participant stated, “It takes a lot of prep to prepare, and materials are not provided by district.” However, it was reported by some participants that resources became more readily available in recent years. A participant indicated, “In the past, a lack of resources was a big deciding factor on teaching STEM. Now, it is much easier to find resources, leading me to teach more engineering design.” Also, participants indicated that they did not have the supplies they need. One participant stated, “Oftentimes when we are asking students to engineer something in the classroom, there is a lack of supplies that are not funded by the teacher.” These comments signify that the lack of resources was an issue of concern for many participants; however, the availability of online resources in recent years has reduced the effect of this factor.

Academic preparation (D2). The second open-ended question incorporated in the survey was, “In your own words, explain if your undergraduate and/or graduate studies prepared or did not prepare you to teach engineering design.” Approximately half of the participants who responded to this open-ended question have a bachelor’s degree as their highest degree. Three of the entire sample have degrees in natural science, and the rest have educational degrees. Eighty-nine participants indicated that their undergraduate or/and graduate studies did not prepare them for teaching EDI. Some participants explained how they learned about EDI after graduation, while some provided suggestions on how they could better prepare. The analysis of participants’ responses to this open-ended question reveals the importance of including engineering design in science methods courses.

The importance of engineering design integrated into science methods courses. Data analysis reveals that it is essential for any teachers' preparation program to include engineering design in science methods courses. Integrating engineering design into science methods courses influences teachers' knowledge about teaching engineering design and perceptions toward including engineering design in K-6. Teachers explained the importance of including engineering design in science methods courses by indicating that engineering design was not presented during their undergraduate or graduate studies. Also, the alternative path of learning about engineering design provided was an experience like taking an engineering design course.

Engineering design in science methods courses was not emphasized. Twenty-two participants indicated that they graduated before engineering design education was adopted in elementary schools. They believe that they would take courses that help them facilitate engineering design activities if they graduated after the official implementation of the NGSS. A participant indicated, "[My undergraduate studies] did not prepare me as I have been out of school for 30 years. Things have changed drastically in the field of education since graduation." Another participant stated, "[My undergraduate studies] did not prepare me much at all. I graduated almost 20 years ago before STEM/STEAM was mainstream." These findings may suggest that teachers believe that current teacher preparation programs include engineering in science methods courses, which helps facilitate EDI.

In addition, some participants indicated that their degrees did not prepare them to teach engineering design, and they need to learn practical strategies to facilitate engineering design. A participant stated, "No, they need more direct instruction in this area." Another participant stated, "No, they gave me basic knowledge of subjects but no application to the classroom." Several participants indicated they have taken engineering courses; however, they believe that their degree did not prepare them to teach engineering design. A participant who indicated that he has taken a chemical engineering course stated, “It did not [prepare me to teach EDI] ... I am still lost most days. And fuddle through it.” Another two participants who have taken courses in computer engineering indicated that their degrees did not prepare them. These findings may indicate that courses in natural science or engineering may not provide adequate pedagogy to prepare teachers to facilitate EDI.

On the other hand, some participants indicated that their degree did prepare them to teach engineering design. A participant indicated, “Yes, it did — I wish I had the chance to teach it.” Several of them explained what exactly they learned that helped them feel prepared. A participant stated, “[My undergraduate studies] did not prepare me to teach engineering design at all. Graduate school somewhat prepared me in offering me different resources to engage the students in class more with hands-on experiences and allowing the students to guide the lessons.” Another participant articulated this point very clearly by saying, “My undergraduate studies prepared me for teaching engineering design by teaching me the basics of engineering first and then teaching me how to integrate that into a classroom setting.” These comments indicate that integrating engineering design into science methods courses may provide the preparation necessary to facilitate EDI.

Alternative learning methods. Twenty-eight participants indicated that their degrees did not prepare them to teach engineering design; however, they explained that they learned about EDI through professional development or self-learning, which prepared them to facilitate EDI.

Many emphasized that, via professional development workshops, they became prepared to facilitate EDI. A participant stated, “I do not feel any college classes prepared me to teach engineering design. The training I have received has been professional development type workshops." Another participant indicated, "My undergraduate studies did not prepare me to teach engineering, [but] professional development has." These comments suggest that teachers who did not have the chance to take a science methods course that included engineering design during undergraduate or graduate school became better prepared to teach engineering design if they attended professional development workshops.

Self-learning is another alternative method of learning about EDI. Some participants indicated that their degrees did not prepare them, and they learned about engineering design by researching and reading about the topic. A participant indicated, "I graduated in 1988. I don't feel I received education classes to teach engineering design. I have researched it on my own, though." Another participant indicated that, "My undergrad did NOT prepare me for teaching engineering design! I have spent time outside of my degree to research and learn about this topic in the classroom." When teachers were not offered an opportunity to learn about engineering design during their studies and did not attend any professional development about teaching EDI, they tended to learn about engineering design independently. A way of learning about facilitating engineering design was via their own experience of implementing engineering design activities in their classrooms. Teachers tended to test and practice different engineering design activities, which helped them become more prepared to facilitate EDI. A participant stated:

> My undergraduate degree did not prepare me to teach engineering design. I understand the basics from my own life experiences and from having completed activities in my classroom, but I've learned all of that in the classroom setting as I go.

This indicates that teachers attended professional development or conducted their own research to prepare and facilitate engineering design activities. Teachers would have a similar learning experience if they had taken engineering design during a science methods course as preservice teachers, which emphasizes the importance of including engineering in science methods courses.

Professional development (D3). The third open-ended question was to explore the effect of professional development on teachers' EDI. The question was, "Please describe how your professional development did or did not affect your engineering design instructions." Forty participants reported that they did not receive professional development. Also, among those who did receive professional development, their responses reveal that they did not receive an equal amount and quality of professional development. The participants revealed the influence of professional development on teachers' EDI and explained why some participants were not offered an opportunity to attend professional development workshops.

The influence of professional development. This concept shows the influence of attending professional development workshops about engineering design. Participants tended to describe exactly what they received and how the training influenced them. Teachers who received professional development describe the benefit of attending professional development from three perspectives, which are a change in perceptions, a source of resources, and an influence on their EDI.

Change in perceptions. This concept reveals that participants experience a change in their perceptions after attending professional development workshops about engineering design. Twelve participants indicated that professional development encourages them to implement engineering design in their classrooms. A participant stated, "PD gets me excited to try new STEM projects in my classroom! I love learning about the new ideas presented in PD." Another change in perception is the change in their self-efficacy of teaching engineering design. A participant stated, "The professional development was encouraging in that it enlightened me on how easy and fun it is to incorporate STEM into the elementary setting." These findings suggest that attendance at professional development opportunities would positively influence teachers' perception toward engineering design.

A source of resources. This concept shows that attending professional development becomes a source of ideas, lesson plans, and materials needed to implement engineering design in classrooms. Fifteen participants who indicated that professional development positively influenced them explained that gaining engineering curricula and materials is one of the main advantages of attending the workshop. A participant indicated, "I have attended STEAM professional developments that gave me simple engineering lessons I could use in my classroom." Another participant stated, "[The professional development] gave me lots of ideas and resources to use when teaching engineering design." Another benefit emphasized by participants is that teachers learn or share new ideas that could be implemented in their classrooms. A participant stated, "[The training] allowed me to hear tasks others created and shared during the professional development session." These comments signify that one of the positive impacts of attending professional development is that it provides the needed resources for teachers to integrate engineering design in their classrooms. Also, this may suggest the availability of engineering instructional design is an issue that limits teachers' ability to implement EDI.

Impact on their EDI. This concept refers to the influence of attending professional development workshops on teachers' EDI. The analysis reveals that attending a workshop that introduces engineering design differs from a workshop that provides information beyond the introductory level.

Participants who indicated that they received less than six hours in professional development tended to describe the impact of professional development to be ineffective. A participant stated, “The professional development did not help prepare me, as it was very brief, and more of a reminder to teach engineering.” Another participant stated, “I don't feel like I've had enough professional development to really understand how to best implement engineering design in my classroom.” This suggests that spending less than six hours in professional development may not help teachers implement engineering design in their classrooms effectively.

Fifteen participants who received engineering design beyond the introductory level indicated that professional development had a significant impact on their EDI. A participant stated, “It helped me tremendously. It provided me resources, practice, and practical examples to take into my classroom.” Another participant stated, “We have had some really good professional development training days fully devoted to STEM, and I feel I have learned more about STEM.” Also, extensive professional development workshops beyond the introductory level help teachers facilitate engineering design with K-3 students. A participant stated,

> The professional development made me take a closer look at how to teach it on a lower level. I teach kindergarten, and those children need a very basic knowledge of engineering design. It helped me weave the subject matter into our daily lessons.

Furthermore, participants who receive workshops beyond the introductory level indicated that professional development helps them fully understand EDP. A participant stated, “I would say the professional development was helpful, as it specifically explained…the steps of the engineering design process and how to incorporate it into our science curriculum." Another participant stated, “The PD's helped me better understand the EDP and how to implement to the kiddos.” This leads the researcher to conclude that attending professional development beyond the introductory level is found to positively influence teachers’ EDI.

Not offered professional development. Forty participants indicated that they did not attend any workshop to learn about EDI. Participants tended to explain why they did not attend professional development and showed the alternative path of learning about engineering design. The analysis of participants’ responses suggests that school priority determines teachers’ opportunities to attend professional development. Also, self-learning is an alternative path for teachers who are not offered professional development.

*School priority***.** Six participants indicated that they did not attend professional development about engineering design because their districts or schools did not offer them a chance. A participant stated, “I have never been to any engineering ones! If I had been asked to go, I would.”. Another participant stated, "I have not received any professional development on this topic. It has never been offered by [the] school district.” Several participants indicated that their districts offer them a chance to attend professional development about reading and math only. A participant stated, “Professional development is usually centered around reading and sometimes math.” This suggests that teachers might be willing to attend professional development about EDI but that schools may have different priorities.

Alternative path. Several participants indicated that they did not receive official training on teaching engineering design and revealed that they learned about engineering design by self-learning**.** A participant stated, “My PD is mostly me watching & learning from teachers on the internet. Our school does not allow us to go to outside [for] PD, and they do not teach any engineering design instruction PD.” These comments suggest that teachers who were not offered an opportunity to attend professional development tended to use online resources to learn.

Belief about teaching engineering design (D4). The fourth open-ended question incorporated in the survey was, “What were your initial views/feelings about the inclusion of engineering design in the NGSS for grade K-6?” Participants revealed strong positive beliefs about the importance of teaching engineering design at the elementary level. Also, some participants responded to this question by showing the difficulties and issues associated with integrating engineering design at their elementary schools. The analytical tools such as open coding, axial coding, and selective coding were used to analyze their responses and reveal their perceptions toward engineering design, the shift in perceptions, and feelings of being burdened and overtaxed.

Perceptions toward engineering design. Perceptions toward engineering design refer to the type of beliefs teachers hold toward teaching engineering design at elementary school. There are two dominating types of beliefs presented in the data, which are positive strong beliefs and neutral beliefs.

Positive beliefs. Forty-eight participants showed positive beliefs about including engineering design in K-6 science standards. A participant stated, “I thought it was a great addition. It really should have been done sooner.” Their opinions vary in terms of why they should include engineering design in their classrooms. Twenty-two participants believe that it is essential because it is exciting and intriguing for students. A participant stated, “I was excited to be able to incorporate engineering into my science lessons because students find it more engaging.” Some participants believe that engineering design is essential because it prepares students for the future and teaches necessary skills. A participant stated, “I think that engineering skills are useful everyday skills from which students can benefit. They need to problem-solve both in their professional and in their home lives, and I think that teaching them these skills is important." These findings indicate many participants believe that including engineering design in K-6 science standards is important because the standards provide an engaging experience and teach essential skills for students.

Neutral beliefs. Twenty-four participants did not support or reject the idea of including the engineering design in elementary classes. A participant stated, "Neutral," and another participant stated, "Impartial." Participants who did not have sufficient knowledge and experience about engineering design tended to not express their opinion about engineering design. A participant stated, "Honestly I know nothing about it." Some participants emphasized that they are not familiar with engineering design. A participant stated, "I am not familiar with engineering design, but including it and exposing students earlier on in life will probably be beneficial to the students." This concept reveals that the lack of sufficient knowledge influences teacher beliefs toward engineering design.

Also, teachers' experiences were found to change their perceptions. A participant stated, "I was terrified! But now I see how beneficial it is and how the kids embrace it and are excited for it without being scared. They LOVE engineering projects!!" Another participant stated,

> My initial view was...How am I going to find time to teach this along with everything else? But I have managed to plan time to teach science with our new science curriculum. It is fun to teach, and the kids really enjoy the projects and experiments.

Barriers and difficulties. This concept refers to the issues revealed by participants regarding the inclusion of engineering design in K-6 science standards. Participants indicated that implementing engineering design at the appropriate at primary grade level, as well as challenges with the school priorities, are concerns associated with including engineering design in K-6 science standards.

Grade level and engineering design. Participants' responses reveal that teachers' beliefs about including engineering design are influenced by grade levels. Kindergarten, first, and second-grade level teachers tended to discuss the issues related to implementing engineering design at lower grade levels. A kindergarten teacher stated,

> I think for higher grade levels this would be awesome. But, I teach kindergarten, and I feel like I don't have as much time to do this. When I have students who still struggle with writing, alphabet names/sounds, and counting, I need to spend my time working with [those challenges].

This suggests that teachers who were assigned to teach at lower grade levels tended to prioritize teaching reading and math. Another issue related to including engineering design at a lower grade level is that the activity should be grade-level appropriate. As a kindergarten teacher stated, "I like teaching it. The students always seem to have fun with it. As long as it is grade-level appropriate, I think it is very engaging." There are two points presented in this concept: students at lower grades need more focus on reading and math, and engineering design activities must be grade-level appropriate to have a positive impact on students.

School priority. This concept reveals that school priority plays an essential role in integrating engineering design. Teachers may not implement engineering design when less emphasis is placed on EDI. A fourth-grade teacher stated, "I honestly have never seen it in fourth grade. We do not state test in science, so it tends to be put aside" This comment suggests that science is not emphasized at the fourth-grade level. When engineering design was not emphasized by the school, teachers struggled to find the time. A participant indicated she does not have enough time to teach engineering design, saying:

> I think they would be great, but there is NO time in our schedules to include anything else. Our students get science once every 6 days as a special [activity], and social studies is incorporated through reading units. Students are expected to learn cursive, how to type, how to regulate their emotions through counseling lessons, and many other things that barely fit into the day.

In addition, the lack of knowledge and resources are other issues that might be caused by a school not prioritizing engineering design. Participants tended to show their excitement for engineering design; however, they indicated that they need training to effectively implement the design. A participant stated that she feels, "A little overwhelmed. Professional development would help." Another participant indicated, "I'd love it, but I know I need training to truly implement it in my classroom." Several participants showed that they want to integrate engineering design; however, the lack of necessary materials, supplies, and curricula are preventing them from integration. A participant stated, "I think it would be a good choice to include engineering design in the standards. I would like to have more curriculum available to teach it adequately." Another participant stated, "I love the idea, but need more resources to do it." These comments reveal teachers' excitement about the inclusion of engineering design in K-6 science standards; however, the lack of time, knowledge, and resources are three factors preventing them from implementation.

Self-efficacy of teaching engineering design (D5). The fifth open-ended question was developed based on Bandura's definition of self-efficacy, which describes self-efficacy as "people's beliefs about their capabilities to produce designated levels of performance" (Bandura, 1994, p. 71). This open-ended question was incorporated in the survey to investigate teachers' self-efficacy of teaching engineering design. The question was, "Please describe how prepared or unprepared do you feel to teach engineering design.” Participants’ responses tended to describe the level of confidence they feel toward teaching engineering design and the factors believed to influence their self-efficacy.

Levels of self-efficacy. Participants’ responses indicated that teachers display varying levels of self-efficacy. The analysis reveals three levels of self-efficacy that include fully prepared and confident, prepared with some limitations, and feeling unprepared.

Fully prepared and confidant. Sixteen participants indicated that they feel prepared and confident in teaching engineering design. A participant stated, "I feel that I am giving students many opportunities for engineering activities at their level.” Another participant indicated that she feels prepared to teach engineering design because she received training in teaching engineering design and has curriculum to help her with the implementation. She stated, “I feel very prepared to teach engineering design through the PLTW curriculum. The training and materials provided help me teach K-6 students about the engineering design process at age-appropriate levels.” These comments indicate that some participants felt fully prepared to teach engineering design. Also, the teachers’ comments suggest that having access to professional development and resources plays a vital role in teachers' self-efficacy.

Prepared with limitations. Thirteen participants indicated that they did not feel adequately prepared to teach engineering design. Several participants believed that they could carry out lesson plans developed by others but could not develop their own lessons. A participant stated, "I can't create my own lessons about ED, but I can carry out lessons prepared by others." Another participant stated, “If I had a detailed plan, I would feel comfortable teaching it.” This level of self-efficacy may explain why many participants strongly emphasize the lack of resources as one of the main obstacles preventing them from adequately facilitating engineering design. Another limitation to their confidence is that they did not feel skilled to facilitate engineering design to multiple grade levels. A participant stated, “At [the] fourth-grade level, I believe I can teach engineering design.” Another participant stated, “Well, I only teach second grade, so I'm pretty okay. If I go up, I would need some help.” These comments suggest that teachers may not feel adequately prepared; however, they feel confidant to teach lessons designed by others at a specific grade level.

Feeling unprepared. Twenty-five participants indicated that they did not feel prepared and confident in teaching engineering design. A participant stated, “I feel very unprepared to teach engineering design.” Another participant stated, “I am totally unprepared for teaching engineering design at any level.” Furthermore, participants who felt unprepared to teach engineering design indicated that the lack of knowledge and experience were the two key factors that influenced their self-efficacy. A participant stated, “I feel pretty unprepared. I have never taught a lesson in engineering design. I would be excited to try it." Another participant stated, “[I am] very unprepared, as I haven't had much exposure to engineering design.” These comments indicate that teachers need to learn about engineering design and have the ability to practice what they learned in their classroom in order to feel confident teaching engineering design.

Factors that impact teacher preparedness and confidence. This concept refers to the factors that participants reported to influence their self-efficacy. The analysis reveals that the factors impacting teachers’ self-efficacy of teaching engineering design are teachers’ knowledge and experience.

Participants’ knowledge about engineering design. Participants’ knowledge about teaching engineering design plays a significant role in their self-efficacy. A participant stated, “I do not feel confident in teaching engineering design because I do not feel like I have enough background knowledge on it." Some participants emphasized that they need professional development to prepare them to teach engineering design to feel confident. A participant stated, "Currently I feel unprepared and would need professional development to become comfortable teaching EDI." Another participant stated, "I need more training to do this confidently."

Independent research and inquiry is a way of learning about teaching engineering design, which makes the teachers feel prepared to teach engineering design. A participant stated, "I feel very prepared... not because of my undergrad training but because I have spent time to learn about and understand the concepts myself." Another participant stated, "I need to do some reading up for myself to be able to teach my students about it. I'm not well versed in engineering design." These comments indicate that teachers' knowledge, whether this knowledge is obtained after attending professional development or through self-learning, is a factor that influences participants' self-efficacy in teaching engineering design.

Participants' experience. Experience in teaching engineering design is reported to have a positive impact on teachers' self-efficacy. A participant reported that she became more confident in teaching engineering design after she taught a single lesson. She stated, "We have a curriculum that we follow, but after teaching it once I became more comfortable in seeking out additional opportunities for [Emotional and Behavioral Disorders] lessons." Furthermore, participants who learned about teaching engineering design may feel unprepared if they did not have the chance to practice what they learned. A participant stated,

> I feel like I could look up engineering design and re-learn how to teach it (the first time I learned about it was undergraduate college). I would not feel 100% confident teaching engineering design because I do not incorporate it into my lessons frequently and I have not had frequent professional development on engineering design.

These comments suggest that teachers’ knowledge about engineering design may not be effective if they did not have continuous experience in teaching engineering design. In addition, teachers may feel less confident because they did not implement engineering design activities more frequently. A participant stated, “I can do basic lessons but am not completely comfortable and often feel I fail. I want to do lessons more frequently.” This comment indicates that experience in teaching engineering design positively influences their level of self-efficacy, and teachers would not feel confident teaching engineering design if they did not have experience or if they teach engineering design less frequently.

Engineering design and science content integration (D6). The sixth open-ended question was incorporated in the survey to understand the extent to which science content was integrated into teachers' EDI. The question was, “Please describe how science content is integrated during your engineering design instruction.” Participants described how they teach science and engineering in their classrooms. The analysis reveals the levels of integration and the factors that influence the integration.

Level of integration. This concept refers to the different levels in which science and EDI are integrated into the classroom. Participants’ responses reveal three levels of integration include, not teaching science or engineering, engineering as an additional task, and concurrent integration of science and engineering during EDI.

Not teaching science or engineering. Seventeen participants stated that they did not teach science to their students. As a participant stated, “I am not in charge of teaching science to my students.” Several participants indicated that they teach science without incorporating any engineering design activity. A participant stated, “I do not currently specifically teach engineering design.” These comments indicate that many participants are not currently teaching science or engineering design to their students because schools did not emphasize science or because science was being taught by other teachers.

Engineering design as an addition. This concept reveals that science content is the primary teaching task, and EDI is an extra activity that may take place at the end of the class time or less frequently during the school year. Engineering design activities were added to the main lesson voluntarily by teachers. A participant stated, "I teach the science content and attempt to add the engineering into that instruction." Teachers tended to spend more time addressing science concepts, while engineering design activities were less emphasized. A participant indicated, "Usually the science content takes the lead, and the engineering design process is not the main focal point." This comment leads the researcher to conclude that science and EDI are not equally emphasized. Engineering design activities are considered an extra activity voluntarily added to the main lesson by teachers.

Concurrent integration. Sixteen participants indicated that science content and engineering design activities were integrated and connected throughout the lesson. They revealed how science and engineering were integrated by providing examples of the science content and the engineering activity used in the past. A participant stated,

> We just completed a PBL task about creating a zoo. Students had to research an animal of their choice, create a zoo habitat, find the area and perimeter, as well as the cost of keeping their animal. They had to work with a partner to construct their exhibit in class with materials provided. Then students worked as a class to put their exhibits together to create a class zoo.

Participants indicated that engineering design activities and science content are required to be taught and connected, as stated by a participant, "I'm always required to teach engineering with science concepts embedded." The concurrent integration of science content and engineering activities are presented in multiple examples provided by participants. Also, this reveals concurrent integration may be required by the school.

Factors that influence science and engineering integration. Many participants revealed that certain factors impact how they integrate science content into their EDI. The analysis indicates that lack of time, curriculum limitations, and alignment with the NGSS are the three factors found to influence science and engineering integration.

Lack of time and grade level. This issue appears among participants who teach at a lower grade level. Some participants reported that science is not emphasized by the school. Furthermore, participants stated that they do not have time to teach science, especially for low-grade level students. A participant stated, "I teach the basics...letter names/sounds, counting, numbers, colors, social and emotional skills. We don't do much with science. There just isn't enough time in the day." Another participant stated, "At the kindergarten level, so many skills, standards, and concepts can be taught during the day -- in reading, math, during technology time, etc." These findings may indicate that at a lower grade level schools did not allocate enough time or resources to teach science.

Curriculum limitations. Curricula are found to play a crucial role in how science content is integrated in EDI. Teachers tended to teach science as prescribed in lesson plans developed by others. A participant stated, "Through the FOSS curriculum, the lessons are prepared to integrate science and engineering." The degree to which science content is integrated may vary from curriculum to curriculum. Curricula adopted by some schools may emphasize science content more than engineering design. As a participant stated, "My district uses FOSS kits. Usually the science content takes the lead, and the engineering design process is not the main focal point."

Some participants indicated that the curricula they used do not integrate science into EDI. A participant stated, “In my current curriculum, engineering design is taught alone, separate from other science content.” On the other hand, some participants emphasized that they integrate the science content into engineering design because the curriculum they used is designed that way. A participant stated, “Our PLTW modules integrate science content into all areas we teach.” These comments indicate that the curriculum selected by the teacher or adopted by the school determines the degree to which science content is integrated into EDI.

Alignment to NGSS. Several participants indicated that science content and engineering design cannot be divided. They illustrated how the NGSS guided them to integrate science into engineering design. A participant stated, “We utilize the science concepts presented in other parts of the NGSS to bolster the engineering design time. For example, after learning about our changes to the earth, students design a structure that can withstand a tsunami.” They indicated that they select and adopt the curriculum that is aligned with the NGSS. A participant stated:

> I integrate it as much as I can. We currently do not have a set curriculum for science, so I have a little more flexibility than some in order to get the NGSS standards met and build in that engineering design.

This indicates that adoption of the NGSS by a school encouraged teachers to adopt the curriculum that is aligned with NGSS, which insures appropriate science content integration in EDI.

Engineering design and students’ science conceptual understanding (D7). The seventh open-ended question was incorporated in the survey to investigate the influence of EDI on students' science conceptual understanding. The question was, “Please explain how effective or ineffective did you find engineering design to teach science content for your students.”

Participants reported that teaching engineering design has a positive impact on students' science achievement. Also, they explain the factors they found to limit the positive impact on their students' science achievement.

Positive influence. Twenty-one participants emphasized the positive impact of EDI on students' science conceptual understanding. Participants who believe that engineering design and science content are supposed to be strongly connected indicated that they found engineering design to be very useful. A participant stated, "Very effective, as I said before I don't think it is separate from science content." Also, integrating science content into EDI was found to help students learn science with a deeper understanding of science concepts. Participants stated, "Can't learn without it. Can't teach without it. Personal experience is more effective; if a student experiences a failure then they are one step closer to understanding the why and how of things." These comments suggest that facilitating EDI that integrates science content is likely to have a positive influence on students' science conceptual understanding.

Issues limiting students' science conceptual understanding. Participants who did not explicitly emphasize the positive impact on students' science conceptual understanding tended to explain the factors influencing the potential positive impact of integrating science content during EDI. These factors include lack of time, lack of knowledge, and curriculum limitations.

Lack of time. The time needed to implement EDI is one of the critical issues for effective EDI implementation. A participant stated, "The concept is effective, but the amount of time I have to teach it causes my instruction to be less effective." Participants who find it ineffective explained that they did not have the time needed for the instruction. A participant stated, "Ineffective. We don't have the class time needed to complete any type of science project." A lack of time is found to reduce science content integrated in EDI, which led to less effectiveness on students' science conceptual understanding.

Lack of knowledge. Participants explicitly indicated that they need more training to facilitate the EDI in a way that positively influences students’ science conceptual understanding. A participant stated, “I would like to know more about it so I can be more effective teaching it.” The recent official adoption of the NGSS is a significant shift in science education, and teachers need more instructions on how they could design and facilitate NGSS-aligned lessons. A participant stated, “I'm currently focusing on basing our science content on the phenomenon. This has been a huge shift for me. I would like to improve using the phenomenon as an anchor that we are constantly referencing back to.” Furthermore, participants reported that implementing an NGSS-aligned curriculum is not an easy task and they need training for a smooth transition to the new standards. A participant stated, “We have a new science curriculum that includes engineering, and we had no professional development on the curriculum, so it hasn't been a piece of cake. We have all been learning together.” This indicates that teachers need more training on how they facilitate engineering design activities.

Curriculum limitations. Five participants indicated that the curriculum they are implementing did not integrate the science content in a way that will positively affect the students' science achievement. A participant stated, “The curriculum that I was given to use did not effectively give my students enough science at their level to make good design decisions.” In addition, many participants reported that finding the material needed for EDI was difficult. A participant stated, “It is very hard to find materials and content to teach science.” Another issue that influenced students' science conceptual understanding was the type of engineering design activities. As a participant explained, “Some grade levels complete more science standards than others during the engineering modules. For example, first grade light and sound covered a lot of science concepts. However, fifth grade robotics doesn't cover as many science standards." This indicates that the quality, availability, and nature of engineering design activity play an essential role in students' science conceptual understanding.

Analysis of Classroom Observations.

The researcher conducted four classroom observations. The EQuIP-OP (Marshall et al., 2010) was used to assess the quality of EDI. See Appendix C. Instructional factors, discourse factors, assessment factors, and curriculum factors are the four categories used to evaluate each lesson. This section presents the results of each classroom observation.

First classroom observation. The researcher conducted the first classroom observation in an elementary school located in the southwest region of Kansas. The teacher developed the lesson for fourth grade students by giving students an opportunity to design a roller coaster and label four areas of the coaster, which included increasing acceleration, decreasing acceleration, constant velocity, and acceleration without a change in speed. The teacher presented the instruction and the materials needed for the activity. Students spent most of their time designing and testing their designs.

Instructional factors. The observation of the classroom revealed that the teacher created EDI to verify students' understanding for some science concepts. Students learned about Newton's first law of motion in previous lessons, and in this lesson, students were tasked with labeling the track. The teacher re-explained the science concepts for the students who failed to label the coaster correctly. Students were mostly active in designing an exciting coaster. The teacher worked as a facilitator during the EDI with minimum guidance. Students were freely working on their designs without incorporating the EDP. Science concepts were not taken into consideration by the students during the activity.

Discourse factors. The teacher’s questions rarely challenged the students' understanding. His questions seem to be focused on one correct answer, and he tended to ask oral questions that did not lead to discussion. The communication during the instruction was typically controlled by the teacher, especially when related to science content. The teacher tended to accept one correct answer and sometimes followed up on students' responses with a further low-level probe.

Assessment factors. Regarding the assessment, the entire EDI served as a task to assess students' science conceptual understanding. Based on the EQuIP-OP rubric criteria, the teacher explicitly encouraged students to reflect on their learning at an understanding level. Students’ prior knowledge was assessed by the teacher at the beginning of the class; however, no modified instructions were observed. The assessments measured mostly factual, discrete knowledge. When the teacher assessed his students, he encouraged them to produce an answer that did not require critical thinking.

Curriculum factors. Science content was not covered in sufficient depth. The lesson provided flexibility for students to design their engineering designs; however, the science content and the engineering design were minimally connected. In terms of organizing and collecting information, students had minor input. They were not asked to collect or organize any information to be analyzed.

Second classroom observation. This classroom observation took place in an elementary school in the southwest region of Kansas. The teacher introduced the challenge to third grade students, explained to them the constraints, and showed them the necessary materials needed for the activity. The task was to create a helmet to protect players from a concussion (a raw egg from cracking). The teacher facilitated an EDP to help students design a solution for their engineering problem.

Instructional factors. The teacher occasionally lectured, and students were engaged in engineering design activity; however, the activity did not integrate any science content. The teacher acted as a facilitator, and students were very active and engaged during the instructions. Students' learning focused on design as a challenge. During the activity, students had to write a plan for the egg helmet that included their design ideas, list the strengths and weaknesses of their design, record and explain what they observed as they tested their design, and write a reflection explaining ideas for improving their design.

Discourse factors. Based on the EQuIP-OP rubric criteria of evaluation instructional practices, the teacher asked questions at analyzing and implication levels. Questions encouraged students to explain, reflect, and evaluate their design. During the instruction, the teacher engaged students in open-ended discussions. Communication occurred between student to student and between the teacher to students. The teacher followed responses with other questions that required reasoning.

Assessment factors. The teacher assessed students' prior knowledge, but there was no evidence of modifying instruction after the formative assessment. The teacher occasionally emphasized questions that required critical thinking. The teacher encouraged students to explicitly reflect their learning at the understanding level. The teacher encouraged students to explain what happens when they dropped the egg. Students then listed the changes needed to improve the design.

Curriculum factors. The depth of content was superficial. No science content was explicitly addressed during the lesson. Students were given some flexibility during the investigation; however, their freedom was related to designing and redesigning the solution. Students organized and recorded information in non-prescriptive ways.

Third classroom observation. After being invited to observe EDI in a school located in the north central region of Kansas, the researcher found the instructions to be a traditional science inquiry lesson. The teacher did not introduce any engineering design activity in the lesson. The lesson was designed to teach third grade students about force, friction, and how to use a force sensor.

Instructional factor. Teachers' instructions were a demonstration of science concepts to the students. During the experiment, Newton's cradle was demonstrated, and no engineering design activities were integrated in the class. As the teacher introduced the concept of friction, she asked students to explore the concept before she provided an explanation. According to the EQuIP-OP rubric, teacher-centered instruction was observed most of the time. The teacher gave constant instruction for the students during the class in order to meet the lesson objective within 30 minutes. Students experienced waning active engagement at the beginning of each phase of the lesson. Their learning focused on the mastery of science content.

Discourse factors. The teacher asked questions at the memorization level. Most of the teacher's questions focused on one correct answer. Several times the teacher challenged students to explain the concepts. The teacher's question rarely led to a discussion. She usually led the communication in a didactic pattern and follow-up questions rarely occurred in the class.

Assessment factors. The teacher assessed students' prior knowledge, but no adjustment to instruction was observed. The overall instructions did not emphasize critical thinking. The teacher encouraged students to express their understanding with the whole class. The teacher sometimes elicited information from students to assess understanding in a written format.

Curriculum factors. The curriculum adopted did not integrate an engineering design activity. It was a science content focus. In terms of learning centrality, students did not engage in an engineering design activity. They were heavily dependent on the teacher's instruction to conduct their investigation. Students organized information in a very prescriptive way.

Fourth classroom observation. The researcher conducted this classroom observation to observe an elementary school class in the central east region of Kansas. This fourth-grade teacher implemented an NGSS- aligned curriculum. During the instructions, students learned about Haiti by reading an article. Also, they learned about skeleton building frames, building code, the Richter scale, and then they built and tested their design by incorporating EDP.

Instructional factors. The instruction helped students to engage in engineering design activities, which led them to develop science conceptual understanding. The teacher asked students to explore science before she provided an explanation. She frequently acted as a facilitator. Students were highly engaged in SEPs during the lesson and clearly focused on the task. Student learning required the application of DCIs and SEPs in new situations.

Discourse factors. The teacher’s questions challenged students at analyzing and implication levels. Students had to explain and justify their reasons. There were several attempts to engage students in discussion. Communication was typically directed by the teacher with occasional input from students. The teacher often followed up responses with probing questions requiring students to justify with reasoning or evidence.

Assessment factors. The teacher constantly assessed student prior knowledge; however, the researcher was not able to observe any modification to the instruction. The teacher facilitated activity and asked questions that required critical thinking. Students were explicitly asked to reflect their learning at an understanding level. The assessments used factual, discrete knowledge and authentic measures. The teacher asked students to complete a task that demonstrated their understanding.

Curriculum factors. The lesson provided in-depth science content with clear and explicit connections made to engineering design activity. The lesson provided prescribed engineering design activities with anticipated results. Students gave minor inputs for designing the solution. The lesson seamlessly integrated the content in engineering design activities.

Analysis of Lesson Plans

The researcher analyzed lesson plans collected from the same four observed participants. These lesson plans served to explore how participants prepared for and intended to implement EDI. The quality of the lesson plans was analyzed using EQuIP-LP (Achieve, 2016). This rubric was designed to analyze lesson plans from the perspective of NGSS three dimensions design alignment, NGSS instructional supports, and monitoring NGSS student progress.

Lesson plan one: *NGSS 3D design.* This fourth-grade lesson was developed to provide an opportunity for students to design a roller coaster. Designing a roller coaster is a challenge that motivates student learning. The lesson was not designed to be aligned with NGSS; thus, all essential elements of three dimensions learning were not addressed. The connection between the engineering design activity and science content occurred when students labeled four areas of the coaster (increasing acceleration, decreasing acceleration, constant velocity, and acceleration without a change in speed). In addition, the activity did not provide any opportunity for students to design their model by following EDP, such as planning, evaluating, and communication, that are all supposed to be implemented in any EDI “Engineering Design Process Models,” (n.d.). There is a connection between designing the roller coaster and integration of certain science concepts; however, the connection is fragile. Students did not apply what they learned to design the solution. Therefore, the researcher did not find any evidence that the lesson included elements of these three dimensions of learning.

NGSS instructional supports. In terms of the relevancy and authenticity, the activity was found to be an exhilarating and authentic experience that motivated students to learn. It did not encourage students to discuss how Newton's law can be presented in different settings. Also, the lesson helped students to understand how a roller coaster may work in the real world. Regarding students' ideas, there was no allocated time for students to share or discuss their ideas with other students or with the teacher. This lesson was designed to demonstrate their understanding of Newton's law. No assigned reading was included in the lesson, and the accuracy of scientific information depended on the teacher's feedback and judgment. Also, there was no evidence of any differentiated instruction provided to the participants. Therefore, the researcher found inadequate evidence that the lesson supports three dimensions of learning for all students.

Monitoring NGSS student progress. The lesson was not developed to be aligned with NGSS. No evidence of three-dimensional learning was observed during the lesson. The lesson did not include scoring guidance or a rubric. The formative assessment relied on teacher experience, and no guidance was provided to the teacher on how to modify the lesson. Therefore, the researcher did not find evidence that the lesson included materials that supported monitoring student progress in all three dimensions.

Lesson plan two: *NGSS 3D design*. The primary phenomenon that drove third grade students' learning was utilizing technology and designing a helmet to protect football players from concussions. Engineering design was the focus in this lesson; however, there was no evidence of three dimensions' integration. The lesson was not designed to be aligned with NGSS; thus, no element of SEPs, DCIs, or CCCs were presented to be addressed in the lesson.

The lesson provided an opportunity for students to plan and create, evaluate, and reflect; however, science content was not integrated in the lesson. Therefore, the researcher found no evidence that the students had the opportunity to design a solution by engaging in three-dimensional learning.

NGSS instructional supports. With respect to the relevance and authenticity of the activity, both football as a game and the helmet as an item were relevant to some students' experiences. The lesson provided an opportunity for students to plan their design, discuss it with peers, and present their final design to the class, all of which indicate that the lesson provided an opportunity for students to express their ideas. In terms of scientific accuracy, no scientific concepts were addressed in the lesson. Also, no guidance was provided by the teacher to support differentiated instruction. The researcher did find adequate evidence that the lesson reflected an authentic and meaningful real-world scenario.

Monitoring NGSS student progress. The lesson did not provide guidance for the teacher to monitor three dimensions of students learning. Also, no scoring rubric was provided. The formative assessment might be conducted by investigating students' verbal, written, and drawn artifacts related to the engineering design. However, no guidance was given by the teacher on how to adjust instruction based on the results of the formative assessments. Therefore, the lesson did not provide adequate opportunity to monitor students in three-dimensional leaning as students designed their solutions.

Lesson plan three: ***NGSS 3D design.*** The lesson's main objective was teaching third grade students how to use a force sensor. This central learning goal was to motivate students to learn about Newton's first law of motion, force, friction, and science practices such as asking questions and collecting and analyzing the data. The lesson designer did not claim that the lesson aligned with NGSS, and no element of the SEPs was included in the lesson. The lesson encouraged students to state a hypothesis, collect data for the sensor, analyze the data, and write the results. Also, the lesson heavily emphasized science concepts such as force, Newton’s law, drag, and friction. However, no element of the DCIs was claimed to be addressed in the lesson. Also, there was no explicit emphasis on the CCCs in this lesson. The lesson helped the students understand science concepts and become familiar with science practices. They were required to conduct some science practices as they learned about Newton’s law in order to learn how to use the force sensor. Therefore, the researcher did not find adequate evidence that the lesson supported three-dimensional learning.

NGSS instructional supports. Regarding authenticity, the lesson provided an opportunity for students to work with a real force sensor to collect and analyze real data. Also, they had to measure friction for the different shoes and discuss how friction was related to their life. They had to answer several questions after they conducted the experiment, which indicated that the lesson provided an opportunity for students to express their ideas. No reliable resource of information was provided to the students that ensured scientific accuracy. The lesson provided a visual representation that may have helped students gain more understanding about conducting the experiment. No guidance was provided on how to meet all students' needs and interests. Therefore, the researcher found inadequate evidence that the lesson supported all students in three-dimensional learning.

Monitoring NGSS student progress. Three-dimensional learning was not emphasized in the lesson to be monitored. Also, the lesson did not include scoring guidance or rubric. The formative assessment could be conducted during the experiment. The teacher may investigate students' oral and written response; however, there was no guidance for the teacher to modify the lesson based on the results of formative assessment. The researcher did not find adequate evidence the lesson supported monitoring student progress in three-dimensional learning.

Lesson plan four: *NGSS 3D design.* Designing a building skeleton frame was the anchoring engineering design problem that drove student learning. Fourth-grade students utilized their prior knowledge about earthquakes, the Richter scale, and shaking tables to design a building skeleton. The lesson connected to physical science by understanding force and earthquake magnitudes. Also, it connected to earth science when the students read a book about an earthquake in Haiti. The lesson addressed specific elements of SEPs. These elements included asking a question, planning and carrying out an investigation, and constructing an explanation. Also, the lesson provided an opportunity for students to develop specific elements of DCIs, such as natural hazards and motion and stability. The lesson did not provide clear evidence of using CCCs, however, cause and effect as a concept presented in CCCs was implicitly addressed throughout the lesson. Regarding the integration of the three-dimensional learning, there was evidence that the students used SEPs in conjunction with the DCI. They learned about earthquakes and the magnitude of the earthquakes, which can destroy buildings. Also, they learned about SEPs as they designed their model. There was not sufficient evidence of incorporating CCCs in the lesson. The researcher found adequate evidence that the lesson was designed to provide an opportunity for students to engage in three-dimensional leaning.

NGSS instructional supports. The lesson was designed to be relevant to students' real-world experiences and to engage students in an authentic scenario. It provided an opportunity for students to see a picture of a building destroyed by earthquakes. Another relevant experience was that students were encouraged to think about a building under construction with its skeleton frame visible. The lesson offered an opportunity for student to express their ideas. They were provided an opportunity to answer three open-ended questions. Regarding scientific accuracy, several resources were used during the lesson, including use of an audiotape and a scientific article related to the subject. Both sources are reliable, which ensured the scientific accuracy. Differentiated instruction was extensively addressed in the lesson. Students followed steps to build their models. The steps were supported by pictures to help those who struggle to read written instructions. In addition, students had the opportunity to listen to audio about earthquakes. Also, there was an extra reading task for those who finished early. Therefore, the lesson provided extensive evidence that the lesson reflected an authentic and meaningful scenario.

Monitoring NGSS student progress. Regarding monitoring students' three-dimensional learning, during the activity of constructing a building skeleton frame, students had to answer questions related to SEPs and DCIs. However, the CCCs were not addressed or monitored. The formative assessment could be performed by observing students' oral or written responses. However, no guidance was provided by the teacher for modifying the instruction based on the formative assessment. Also, the lesson did not include a rubric or scoring guidance. Therefore, the researcher found inadequate evidence that the lesson supported monitoring students' progress in three-dimensional learning.

Qualitative Summary

In this qualitative analysis, seven open-ended questions were incorporated in the survey to collect further explanations about participants' experience and academic preparation, professional development, self-efficacy of and beliefs about teaching engineering design, science content integration, and students' science conceptual understanding. Figure 4.2 presents a qualitative summary of the open-ended questions.

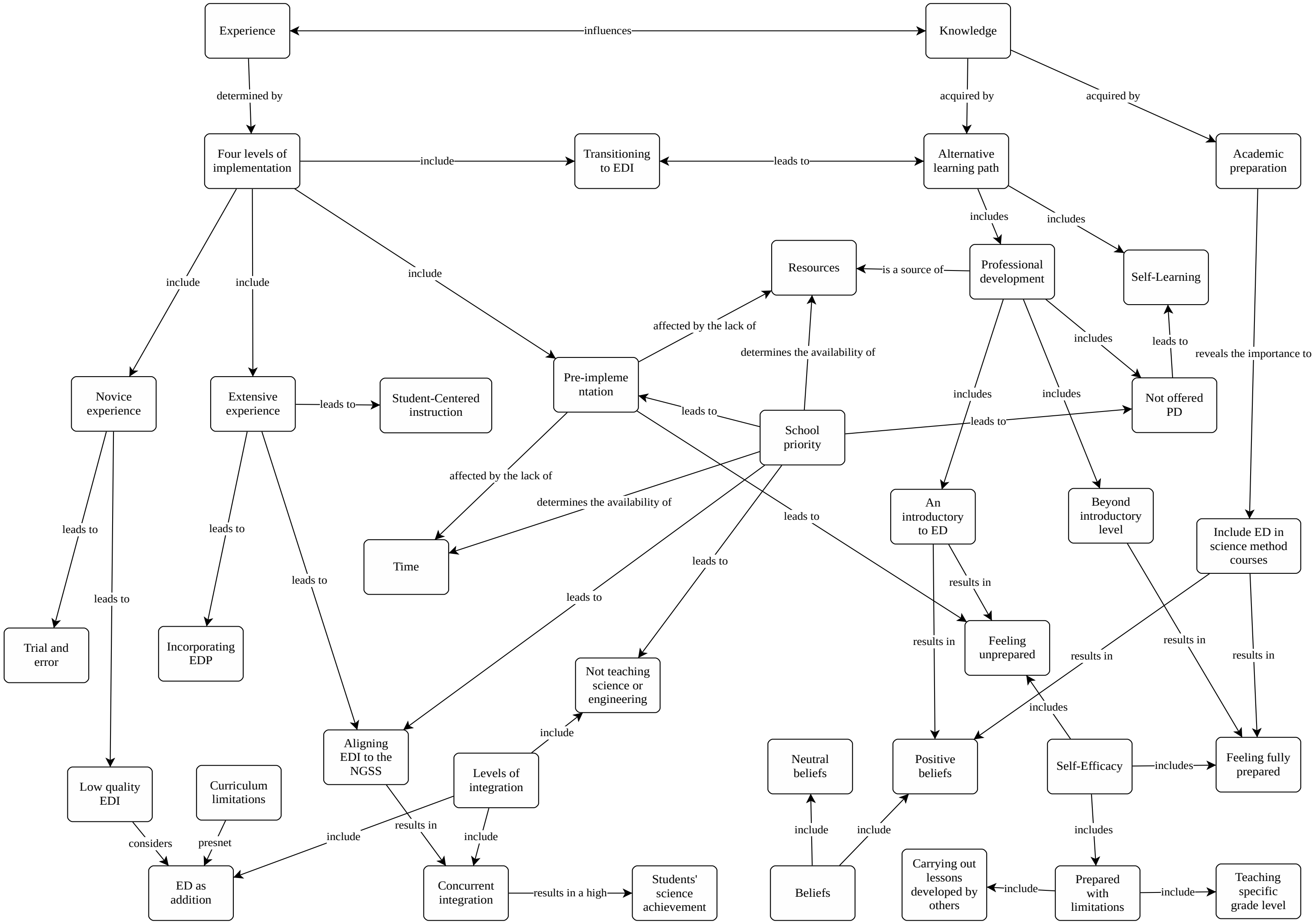


Figure 4.2. The concept map presents the summary of the qualitative data results for the domains of the open ended questions.

Also, teachers’ EDI as planned (lesson plan) and delivered (lesson observation) were captured through classroom observations and documents analysis. Teachers' knowledge about engineering design, whether this knowledge was obtained during their academic preparation or through alternative methods such as professional development and self-learning, were found to have a positive impact on teachers' beliefs and self-efficacy. Also, teachers’ experience in teaching engineering design was found to be influenced by the knowledge of engineering design and schools’ priority. Regarding science content integration, the findings reveal that teachers tended to not teach engineering design, considered engineering design as an additional task, or simultaneously integrated science and engineering into their lessons. Finally, students' science conceptual understanding was found to be positively influenced by a concurrent integration of science and EDI that aligned with the NGSS and was facilitated by teachers with extensive experience in teaching engineering design.

Quantitative Data Analysis

In this section, the researcher presents a detailed descriptive and statistical analysis of the quantitative data. Participants' demographics, the validity and reliability of the scales used to measure the two dependent variables (science content integration and students’ science conceptual understanding), barriers to teaching engineering design, and statistical analysis of the demographical data are presented before proceeding to the main data analysis for research questions two through five.

Participant Demographics

In this study, the demographic information of 222 elementary teachers includes gender, ethnicity, school Title I eligibility, teaching experience, length of experience in teaching science, grade level taught, and the frequency in teaching engineering design (see Table 4.2). The descriptive results indicate that participants were 5.9% male (*N* = 13), 93.7% female (*N* = 208), and 0.5% of the participants were unspecified (*N* = 1). Participants' ethnicity consists of 1.4% American Indian or Alaska Native (*N* = 3), 1.8% Hispanic or Latino (*N*= 1.8), 94.4% White (*N* = 209), and 1.4% of the participants were unspecified (*N* = 3). Eighty-one percent of the participants were from Title I eligible schools (*N* = 180), while 18.9% were not from Title I eligible schools (*N* = 42). In addition, the results indicate 24.1% of the participants reported their years of teaching experience range from one to five (*N* = 52), 23.6% had six to ten years of experience (*N* = 51), 18.1% had an experience range from 11 to 15 years (*N* = 39), 11.6% had 16 to 20 years of experience (*N* = 25), and 22.7% had over 20 years of experience (*N* = 49). Also, participants' responses reveal that participants teach at different grade levels. Fourteen and a half percent of the participants indicated that they did not teach (*N* = 32), 19.5% teach kindergarten students (*N* = 43), 19.1% teach first grade students (*N* = 42), 15.5% teach second grade students

Table 4.2

Summary of In-Service Elementary Teachers' Demographic Information.

Demographical variables	Type	Total number	Percent	Valid percent
Gender	Male	13	5.9	5.9
	Female	208	93.7	93.7
	Undetermined	1	.5	.5
Missing		0	0	
Ethnicity/race	American Indian or Alaska Native	3	1.4	1.4
	Hispanic or Latino	4	1.8	1.8
	White	209	94.1	95.4
	Undetermined	3	1.4	1.4
Missing		3	1.4	
Title I eligible	Yes	180	81.1	81.1
	No	42	18.9	18.9
Missing		0	0	

Table 4.2

Continued.

Demographical variables	Type	Total number	Percent	Valid percent
Years of experience	1 to 5	52	23.4	24.1
	6 to 10	51	23.0	23.6
	11 to 15	39	17.6	18.1
	16 to 20	25	11.3	11.6
	over 20	49	22.1	22.7
Missing		6	2.7	
Experience in teaching science (years)	1 to 5	64	28.8	39.0
	6 to 10	34	15.3	20.7
	11 to 15	19	8.6	11.6
	16 to 20	12	5.4	7.3
	over 20	35	15.8	21.3
Missing		58	26.1	
Teaching grade level	Kindergarten	43	15.9	19.5
	First grade	42	15.6	19.1
	Second grade	34	12.6	15.5
	Third grade	36	13.3	16.4
	Fourth grade	35	13.0	15.9
	Fifth grade	31	11.5	14.1
	Sixth grade	17	6.3	7.7
	Did not teach science	32	11.9	14.5
Missing		0	0	
Frequency of teaching ED	Never	49	22.1	22.1
	A few times a year	83	37.4	37.4
	Once or twice a month	49	22.1	22.1
	Once or twice a week	19	8.6	8.6
	Daily or almost daily	7	3.2	3.2
	Other	15	6.8	6.8
Missing		0	0	

(*N* = 34), 16.4% teach third grade students (*N* = 36), 15.9% teach fourth grade students (*N* = 35), 14.1% teach fifth grade students (*N* = 31), and 7.7% teach sixth grade students (*N* = 17). Regarding how frequently the participants teach engineering design during the school year, their responses indicate that the frequency of teaching engineering design ranges from having never taught engineering design to teaching engineering design daily. Of the participants, 22.1% indicated that they never taught engineering design (*N* = 49), 37.4% taught engineering designs a few times a year (*N* = 83), 22.1% taught engineering design once or twice a month (*N* = 49), 8.6% taught engineering design once or twice a week (*N* = 19), 3.2% taught engineering design daily or almost daily (*N* = 7), and 6.8% reported different responses (*N* = 15).

Validity Check

Two factor analysis tests were conducted to investigate the validity of the scale. The first test examined the validity of the scale that measures science content integration. The results indicate that the factor loading of communalities ranges from .56 to .80. Also, the scree plot reveals that there is only one factor, which is science content integration (see Table 4.3).

Table 4.3

Summary of factor analysis results for science integration scale

Items	Factor Loading
	Science Content Integration
1. Provide direct instruction to explain science concepts	.756
2. Use activity sheets to reinforce skills or content	.562
3. Go over science vocabulary	.793
4. Apply science concepts to explain natural events or real-world situations	.809
5. Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)	.781
6. Discuss students’ prior knowledge or experience related to the science topic or concept	.801
7. Encourage students to explain concepts to one another	.629
Eigenvalues	5.1
Variance	73.3

The second factor analysis test was conducted to investigate the validity of the scale that measures students’ science conceptual understanding. The results indicated factor loading of the communalities range from .67 to .82 and the scree plot suggested that there is a single factor, which is science conceptual understanding. See Table 4.4 for a summary of the factor analysis results for students’ science conceptual understanding scale.

Table 4.4

Summary of factor analysis results for students’ science integration scale

Items	Factor Loading
	Students’ Science Conceptual Understanding
1. Identify questions from observations of phenomena	.670
2. Write about what was observed and why it happened	.745
3. Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	.601
4. Explain the reasoning behind an idea	.805
5. Create reasonable explanations of results of an experiment or investigation	.825
6. Engage in content-driven dialogue	.677
Eigenvalues	4.323
Variance	72.0

Reliability of Measuring Scales

Cronbach’s alpha was conducted to measure the reliability of beliefs, self-efficacy, teacher science integration, and students' science conceptual understanding scales. The results indicate that all scales had a coefficient alpha above .88 (see Table 4.5).

Table 4.5

Summary of Cronbach’s alpha for all measuring scales.

Scales	Number of items	Cronbach’s alpha
Beliefs	7	.98
Self-efficacy	5	.88
Teacher science integration	7	.93
Student science integration	6	.92

Barriers to Teaching Engineering Design

Five items in the survey were designed to measure the perceived barriers to teaching engineering design. The results reveal 47% of the participants reported the lack of knowledge as a strong or a very strong barrier to teaching engineering design, (*N* = 95). Also, the results reveal 51.6% of participants reported the lack of professional development as a strong or a very strong barrier, (*N* = 113). The lack of time was reported by 64.7% to be a strong or very strong barrier, (*N* = 141). However, the lack of administrative support and the lack of experience in engaging diverse learners were not perceived by the majority to be a barrier, 55.7%, (*N* = 121) and 50.7%, (*N* = 111), respectively. See Figure 4.3.

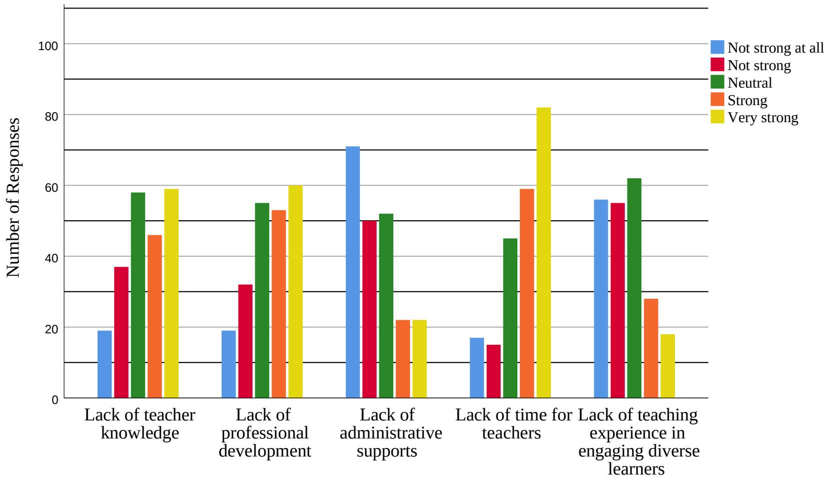


Figure 4.3. Participants' responses to items as barriers to integrating engineering design.

Statistical Analysis of the Demographical Data

The researcher conducted independent t-tests and one-way ANOVA to investigate the impact of gender, school Title I eligibility, and participants' ethnicity on science content integration and students' science conceptual understanding.

Gender. An independent t-test was performed to investigate if there is a difference between males and females on the two dependent variables. The results indicate no statistically significant differences between males and females on science content integration, *t*(160) = -1.953, *p* = .053, and students science conceptual understanding, *t*(161) = -.602, *p* = .548. See Table 4.6 for a summary of the t-test analysis.

Table 4.6

Summary of t-test analysis comparing males and females on science content integration and students' science conceptual understanding.

Variable	Male		Female		t-test
	M	SD	M	SD	
Science content integration	2.76	.775	3.40	.790	-1.953
Students' science conceptual understanding	2.72	.750	2.92	.796	-.602

Title I eligible school. Another independent t-test was conducted to investigate if there is a difference between participants who teach in Title I eligible schools and those who do not on science content integration and students' science conceptual understanding. The results indicate that there is no statistical significant differences in science content integration, t(161) = -.374, *p* = .709, and students' science conceptual understanding, t(162) = .316, p = .752, based on school Title I eligibility. See Table 4.7 for a summary of the t-test analysis.

Ethnicity. A one-way ANOVA was conducted to investigate if there is a difference between the three ethnic groups in the two dependents variables. The number of participants from the rest of the ethnic groups was not sufficient to be included in the analysis. The results indicate that there is no difference based on participants' ethnicity in science content integration, *F*(3, 158) = .112, *p* = .953 and students' science conceptual understanding, *F*(3, 159) = .143, *p* = .934.

Table 4.7.

Summary of t-test analysis comparing school Title I eligibility on science content integration and students' science conceptual understanding.

Variable	Title I eligible		Title I ineligible		t-test
	M	SD	M	SD	
Science content integration	3.36	.776	3.42	.865	-.374
Students' science conceptual understanding	2.92	.799	2.87	.770	.316

Research Questions Two and Three

2- Do elementary in-service teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) influence science content integration in engineering design instruction?

3- Do elementary in-service teachers' preparation (academic preparation, degree level, professional development, and engineering design teaching experience) influence students' science conceptual understanding?

The researcher conducted MANOVA test to investigate if there is an impact of academic preparation, degree level, professional development, and engineering design teaching experience on the two dependent variables (science content integration in EDI and students' science conceptual understanding). The results of each independent variable are presented below.

Academic preparation. To measure the influence of teachers' academic preparation on science content integration and students' science conceptual understanding, the researcher divided the participants into three groups: participants with educational degrees, participants with educational degrees who have taken advanced courses in science, and participants who took engineering courses during their undergraduate and graduate studies. The analysis reveals that

63.6% of the participants have their degrees in education and have never taken any advanced courses in science (N = 110), 28.9% have their degrees in education and have taken advanced courses in science (N = 50), and only 7.5% took engineering courses during their undergraduate and graduate courses (N = 13). See Table 4.8.

Table 4.8.

Summary of in-service elementary teachers' academic preparation

Variable	Type	Total number	Percent	Valid percent
Academic preparation	Majored in education	110	63.6	63.6
	Have taken advanced courses in science	50	28.9	28.9
	Have taken engineering courses	13	7.5	7.5

A MANOVA test was conducted to measure the impact of teachers' academic preparation on the two dependent variables. Pillai's trace was preformed because we have unequal sample size. The results revealed no statistically significant impact of teachers' academic preparation on science content integration and students' science conceptual understanding, *V* = .027, *F*(4, 312) = 1.07, *p* = .370.

Degree level. The descriptive analysis of the participants' degree level indicates that 49.7% of the participants have a bachelor's degree as their highest degree (*N* = 85) and 50.3% hold a master's degree (*N* = 86). See Table 4.9. A MANOVA test was conducted to measure the influence of participants' degree level on science content integration and students' science conceptual understanding. Using Wilks' lambda, the results indicate there was no statistically significant impact of teachers' degree level on science content integration and students' science conceptual understanding, *V* = .998, *F*(2, 154) = .148, *p* = .862.

Table 4.9.

Summary of in-service elementary teachers' degree level.

Variable	Type	Total number	Percent	Valid percent
Degree level	Bachelor's degree	85	49.1	49.7
	Master's degree	86	49.7	50.3

Professional development. Regarding the amount of time participants spent on professional development in engineering design or engineering teaching in the last three years, the findings indicate that 28.5% of the participants have not attended any professional development in engineering or engineering teaching (*N* = 49), 37.6% spent less than six hours in professional development (*N* = 65), 19.2% spent between six and 15 hours (*N* = 33), and 14.5% spent more than 16 hours (*N* = 25). See Table 4.10.

Table 4.10.

Summary of the amount of time in-service elementary teachers spent on professional development.

Variables	Type	Total number	Percent	Valid percent
Professional development	Never	49	28.3	28.5
	Less than 6 hours	65	37.6	37.6
	6–15 hours	33	19.1	19.2
	More than 16 hours	25	14.5	14.5

A MANOVA test was conducted to measure the impact of professional development on the two dependent variables. Preliminary assumption testing was conducted to check for normality, linearity, homogeneity of variance-covariance matrices, and multicollinearity. The researcher did not notice any violation of the assumptions. Pillai's trace was preformed because we have unequal sample size. The result revealed a statistically significant difference in science content integration and students' science conceptual understanding based on the amount of time teachers spent in professional development, $V = .179$, $F(6, 308) = 5.044$, $p < .001$. Follow-up univariate ANOVAs indicate that both science content integration and students' science conceptual understanding were significantly influenced by the time spent on professional development, $F(3, 154) = 5.19$, $p = .002$, $\eta_2 = .092$ and $F(3, 154) = 10.29$, $p < .001$, $\eta_2 = .16$, respectively. Post hoc analysis using Bonferroni post hoc criterion for significance indicates that for science content integration, there was a significant pairwise difference between participants who never attended professional development and participants who spent 16 hours or more, Also, there is a significant difference in science content integration between participants who attended less than six hours and participants who spent more than 16 hours. See Table 4.11.

Table 4.11.

Pairwise mean differences, p values and confidence intervals for science content integration by professional development.

(I) Time spent on professional development	(J) Time spent on professional development	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Never	Less than 6 hours	-.029	.152	1.000	-.435	.377
	6–15 hours	-.450	.178	.077	-.928	.027
	More than 15 hours	-.617	.203	**.017***	-1.162	-.072
Less than 6 hours	Never	.029	.152	1.000	-.377	.435
	6–15 hours	-.421	.166	.075	-.866	.024
	More than 15 hours	-.588	.193	**.017***	-1.105	-.071
6–15 hours	Never	.450	.178	.077	-.027	.928
	Less than 6 hours	.421	.166	.075	-.024	.866
	More than 15 hours	-.166	.215	1.000	-.741	.408
More than 15 hours	Never	.617	.203	**.017***	.072	1.162
	Less than 6 hours	.588	.193	**.017***	.071	1.105
	6–15 hours	.166	.215	1.000	-.408	.741

*Bonferroni corrected significant alpha level. $p < 0.025$.

Inspection of the means indicates that participants who spent 16 hours or more in professional development (*M* = 3.8, *SD* = .58) were integrating science content in their EDI more than participants who never attended professional development (*M* = 3.2, *SD* = .85), *p* = .017 or participants who spent less than six hours (*M* = 3.2, *SD* = .76), *p* = .017.

For students' science conceptual understanding, post hoc analysis indicate that there was a significant pairwise difference between participants who never attended professional development and participants who spent 6 -15 hours and 16 or more hours. Also, there was a significant difference in students' science conceptual understanding between participants who spent less than six hours, 6 -15 hours, and 16 or more hours (see Table 4.12).

Table 4.12

Pairwise mean differences, p values and confidence intervals for students' science conceptual understanding by professional developments.

(I) Time spent on professional development	(J) Time spent on professional development	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Never	Less than 6 hours	-.012	.144	1.000	-.399	.373
	6–15 hours	-.691	.170	**.000***	-1.146	-.236
	More than 15 hours	-.686	.193	**.003***	-1.205	-.168
Less than 6 hours	Never	.012	.144	1.000	-.373	.399
	6–15 hours	-.678	.158	**.000***	-1.102	-.255
	More than 15 hours	-.674	.183	**.002**	-1.165	-.182
6–15 hours	Never	.691	.170	**.000***	.236	1.146
	Less than 6 hours	.678	.158	**.000***	.255	1.102
	More than 15 hours	.004	.204	1.000	-.542	.551
More than 15 hours	Never	.686	.193	**.003***	.168	1.205
	Less than 6 hours	.674	.183	**.002***	.182	1.165
	6–15 hours	-.0047	.204	1.000	-.551	.542

*Bonferroni corrected significant alpha level. *p* < 0.025.

Inspection of the means indicates that students whose teachers spent more than 16 hours in professional development ($M = 3.36$, $SD = .51$) reported higher science conceptual understanding compared to students whose teachers spent less than six hours ($M = 2.69$, $SD = .71$), $p = .002$ or never attended professional development ($M = 2.67$, $SD = .87$), $p = .003$. Also, students whose teachers spent 6 - 15 hours ($M = 3.36$, $SD = .64$) reported higher science conceptual understanding compared to students whose teachers spent less than six hours ($M = 2.69$, $SD = .71$), $p < .001$ or never attended professional development, $p < .001$.

Engineering design teaching experience. Participants reported to have different experiences of teaching engineering design, ranging from not having any experience to over five years of experience. Twenty-four point three percent indicated that they do not have experience in teaching engineering design ($N = 27$), 25.2% have two years or less experience ($N = 28$), 36.0% have three to five years of experience ($N = 40$), and 14.4% have more than five years of experience ($N = 16$). See Table 4.13.

Table 4.13.

Summary of in-service elementary teachers' experience in teaching engineering design

Variable	Type	Total number	Percent	Valid percent
Experience teaching engineering design	No experience	27	15.6	24.3
	1 to 2 years	28	16.2	25.2
	3 to 5 years	40	23.1	36.0
	Over 5 years	16	9.2	14.4

A MANOVA test was conducted to measure the impact of experience in teaching engineering design on science content integration and students' science conceptual understanding. Preliminary assumption testing was conducted to check for normality, linearity, homogeneity of variance-covariance matrices, and multicollinearity. Levene's assumption was violated for science content integration, $F(3, 100) = 5.49$, $p = 0.002$, and students' science conceptual understanding, $F(3, 100) = 3.04$, $p = 0.032$. In such cases, the researcher used Pillai's trace to determine the significance of multivariate effects and a more conservative alpha level (<.025) was adopted for inference tests as suggested by Tabachnick and Fidell, (2001). The results indicate a significant difference in the two dependent variables based on engineering design teaching experience, $V = .140$, $F(6, 200) = 2.50$, $p = .023$. Follow-up univariate ANOVAs indicate that both science content integration and students' science conceptual understanding were significantly different for teachers with different engineering design teaching experience, $F(3, 100) = 3.98$, $p = .010$, $\eta_2 = .107$ and $F(3, 100) = 5.05$, $p =.003$, $\eta_2 = .132$, respectively.

Table 4.14

Pairwise mean differences, p values and confidence intervals for science content integration by engineering design teaching experience

(I) Engineering design teaching experience	(J) Engineering design Teaching experience	Mean difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower bound	Upper bound
No experience	1 to 2	-.516	.214	.106	-1.093	.060
	3 to 5	-.655	.195	**.007***	-1.182	-.129
	over 5 years	-.538	.262	.256	-1.244	.167
1 to 2	no experience	.516	.214	.106	-.060	1.093
	3 to 5	-.139	.195	1.000	-.665	.387
	over 5 years	-.022	.262	1.000	-.728	.684
3 to 5	no experience	.655	.195	**.007***	.129	1.182
	1 to 2	.139	.195	1.000	-.387	.665
	over 5 years	.117	.247	1.000	-.548	.783
Over 5 years	no experience	.538	.262	.256	-.167	1.244
	1 to 2	.022	.262	1.000	-.684	.728
	3 to 5	-.117	.247	1.000	-.783	.548

*Bonferroni corrected significant alpha level. $p < 0.025$.

Furthermore, the results indicate that for science content integration, a significant pairwise difference exists between participants who have no experience in teaching engineering design and participants who have three to five years of experience. See Table 4.14.

Inspection of the means indicates that participants who have three to five years of experience in teaching engineering design (*M* = 3.64, *SD* = .64) reported integrating science content in their EDI more than participants who have no experience (*M* = 2.98, *SD* = 1.13), *p* = .007.

Also, there is a significant difference in students' science conceptual understanding between participants who have no experience and participants who have one to two years of experience and three to five years of experience. See Table 4.15.

Table 4.15

Pairwise mean differences, p values and confidence intervals for students' science conceptual understanding by engineering design teaching experience

(I) Engineering design teaching experience	(J) Engineering design teaching experience	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval Lower bound	95% Confidence interval Upper bound
No experience	1 to 2	-.6410*	.214	**.021***	-1.219	-.063
	3 to 5	-.7137*	.196	**.003***	-1.241	-.186
	over 5 years	-.6538	.263	.087	-1.361	.054
1 to 2	no experience	.6410*	.214	**.021***	.063	1.219
	3 to 5	-.0726	.196	1.000	-.600	.455
	over 5 years	-.0128	.263	1.000	-.720	.695
3 to 5	no experience	.7137*	.196	**.003***	.186	1.241
	1 to 2	.0726	.196	1.000	-.455	.600
	over 5 years	.0598	.247	1.000	-.607	.727
Over 5 years	no experience	.6538	.263	.087	-.054	1.361
	1 to 2	.0128	.263	1.000	-.695	.720
	3 to 5	-.0598	.247	1.000	-.727	.607

*Bonferroni corrected significant alpha level. $p < 0.025$.

Inspection of the means indicates students whose teachers have three to five years of experience (*M* = 3.16, *SD* = .72) reported higher science conceptual understanding as compared to students whose teachers have no experience (*M* = 2.44, *SD* = 1.02), *p* = .003. Also, students whose teachers have one to two years of experience (*M* = 3.08, *SD* = .55) demonstrate more science conceptual understanding compared to students whose teachers have no experience in teaching engineering design (*M* = 2.44, *SD* = 1.02), *p* = .021.

Research Question Four

Is there a correlation between elementary in-service teachers' self-efficacy for and beliefs about teaching engineering design and science content integration in engineering design instruction?

To answer this research question, the researcher incorporated BSEEE-T instrument in the survey to measure teachers' self-efficacy for teaching engineering design and teachers' beliefs about teaching engineering design. Pearson Correlation was conducted to investigate the relationship between teachers' self-efficacy for teaching engineering design (*M* = 3.14, *SD* = 1.14) and science content integration (*M* = 3.37, *SD* = .79) The results indicate the relationship is negative, weak and statistically significant between the two variables, *r*(161) = - .248, *p* = .002. (two-tailed). The findings also indicate that there is no statistically significant relationship between teachers' beliefs about teaching engineering design (*M* = 2.84, *SD* = 1.76) and science content integration, *r*(162) = - .092, *p* =.245 (two-tailed). See Table 4.16.

Table 4.16.

Summary of correlation analysis.

Scales	*M*	*SD*	1	2	3	4
1. Beliefs	2.84	1.76	-			
2. Self-efficacy	3.14	1.14	.470**	-		
3. Science content integration	3.37	.79	-.092	-.248**	-	
4. Students' science conceptual understanding	2.91	.79	-.095	-.237**	.790**	-

** *p* < .01 (2-tailed)

Research Question Five

Is there a correlation between elementary in-service teachers' self-efficacy for and beliefs about teaching engineering design and students' science conceptual understanding?

A Pearson correlation test was conducted to investigate the relationship between teachers’ self-efficacy for teaching engineering design (*M* = 3.14, *SD* = 1.14) and teachers’ perception of student’s science conceptual understanding (*M* = 2.91, *SD* = .79). The results indicate that the relationship between the two variables was negative, weak in strength, and statistically significant, *r*(162) = - .237, *p* = .002. These results suggest that teachers with higher self-efficacy reported their students demonstrated high science conceptual understanding more frequently. Also, the Pearson correlation test was conducted to investigate the relationship between the teachers’ beliefs about teaching engineering design (*M* = 2.84, *SD* = 1.76) and students’ science conceptual understanding (*M* = 2.91, *SD* = .79). The results reveal no statistically significant difference between the two variables: *r*(163) = - .095, *p* = .229. See Table 4.16.

Mixed-Methods Analysis

Research Question Six

Do the qualitative results reveal similar findings of the factors affecting science content integration and students’ science conceptual understanding as the findings of the quantitative analysis?

After analyzing the qualitative and quantitative data, the results from the two types of data were compared to identify the similarities and differences. A summary of the qualitative and quantitative results is presented in Table 4.17. The comparison between the two data sets reveals a similar result in terms of the influence of teachers' preparation, professional development,

Table 4.17

A summary of the qualitative and quantitative findings

Domains	Qualitative findings (from the open-ended responses)		Quantitative findings
Academic preparation and degree level	**The importance of including engineering design in science methods courses** Engineering design was not emphasized Alternative learning methods Professional development Self-learning		1- No significant impact of teachers’ academic preparation on science content integration and students’ science conceptual understanding, *V* = .027, *F*(4, 312) = 1.07, *p* = .370. 2- No significant impact of teachers’ degree level on science content integration and students’ science conceptual understanding, *V* = .998, *F*(2, 154) = .148, *p* = .862.
Professional development	**The influence of professional development** Change in perceptions A source of resources Impact on their EDI Introduction to engineering design workshop Beyond introductory workshop level	**Not offered professional development** School priority	1- A significant difference in science content integration and students' science conceptual understanding based on the amount of time teachers spent in professional development, *V* = .179, *F*(6, 308) = 5.044, *p* < .001. 2- Science content integration and students' science conceptual understanding were significantly influenced by the time spent on professional development, *F*(3, 154) = 5.19, *p* = .002, η_2 = .092 and *F*(3, 154) = 10.29, *p* < .001, η_2 = .16
Experience	**Levels of EDI implementation** Pre-implementation Transitioning to EDI Novice experience Trial and error The quality of EDI Extensive experience Student-centered Incorporate EDP	**Obstacles for pre-implementation and novice experience** Lack of time Lack of knowledge Lack of resources	1- A significant difference in science content integration and students' science conceptual understanding variables based on engineering design teaching experience, *V* = .140, *F*(6, 200) = 2.50, *p* = .023 2- Science content integration and students' science conceptual understanding were significantly different for teachers with different engineering design teaching experience, *F*(3, 100) = 3.98, *p* = .010, η_2 = .107 and *F*(3, 100) = 5.05, *p* =.003, η_2 = .132, respectively

Table 4.17

continued.

Domains	Qualitative findings (from the open-ended responses)		Quantitative findings
Self-efficacy	**Level of self-efficacy** Fully prepared and confidant Prepared with limitations Feeling unprepared	**Factors impacting their self-efficacy** Participants' knowledge about EDI Participant experience	1. A significant relationship between science content integration and self-efficacy, $r(161) = -.248$, $p = .002$. (two-tailed) 2. A significant relationship between students' science conceptual understanding and self-efficacy $r(162) = -.237$, $p = .002$
Beliefs	**Perceptions toward ED** Positive beliefs Neutral beliefs Experience and change in beliefs	**Barriers and difficulties** Grade level and EDI School priority	1- No relationship between the teachers' beliefs about teaching engineering design ($M = 2.84$, $SD = 1.76$) and students' science conceptual understanding, $r(163) = -.095$, $p = .229$ 2- No relationship between teachers' beliefs about teaching engineering design ($M = 2.84$, $SD = 1.76$) and science content integration, $r(162) = -.092$, $p = .245$ (two-tailed)
Science content integration	**Level of integration** Not teaching science or engineering Engineering design as addition Concurrent integration	**Factors influencing science and engineering integration** Lack of time and grade level Curriculum limitation Alignment to NGSS	1- 24.3% reported that they do not have experience in teaching engineering design 2- 28.5% have not attended any professional development ($N = 49$). 3- 37.6% spent less than six hours in professional development ($N = 65$). 4- 47% of the participants reported that the lack of knowledge is a strong or a very strong barrier 5- The lack of time is reported by 64.6% to be a strong or very strong barrier
Students' science conceptual understanding	**Issues limiting students' science conceptual understanding** Lack of time Lack of knowledge Curriculum limitations	**Positive influences**	

experience teaching engineering design, and self-efficacy. Also, the results reveal dissimilarities in the influence of teachers' beliefs and curriculum limitations.

Convergence. Qualitative and quantitative data converge when there is a similarity between the results of the two data sets. The convergent data analysis reveals teachers' academic preparation, as mentioned in the open-ended responses, did not prepare in-service teachers to teach engineering design. This result was reflected in the quantitative data by not finding a significant impact of teachers' academic preparation and degree level on science content integration and students' science conceptual understanding.

Also, the two data sets reveal that professional development greatly influences teachers' EDI. Furthermore, both findings reveal that introductory workshops about engineering design or spending less than six hours in professional development did not impact teachers' EDI compared to more extensive workshops. Additionally, the convergent data analysis indicates experienced participants tend to implement high-quality EDI, incorporate EDP, and adopt a curriculum that aligns with the NGSS as compared to novice teachers. Similarly, the quantitative results indicate a significant impact of engineering design teaching experience on science content integration and students' science conceptual understanding.

Another convergence in the data reveals participants’ knowledge and experience, as mentioned in the open-ended questions, influence teachers’ self-efficacy. Similarly, the quantitative results indicate that participants' self-efficacy significantly correlate to science content integration and students' science conceptual understanding. Also, the qualitative data reveal the essential role of the availability of time and knowledge in how science content is integrated and influences students' science conceptual understanding. Similarly, the quantitative data indicate most participants reported that lack of time and knowledge was a barrier to teaching engineering design.

Divergence. Qualitative and quantitative data diverged when the data sets were dissimilar. Open-ended questions, classroom observations, and documents analysis reveal the curriculum limits how EDI was integrated; however, the quantitative instrument was not designed to measure the impact of the curriculum.

Another divergence in the data is that the qualitative data reveal that participants' experience positively influences their beliefs about teaching EDI, which suggests that experienced participants tend to have a robust positive belief compared to participants with no experience. However, the quantitative data did not find any relationship between participants' beliefs and science content integration or students' science conceptual understanding.

Summary

This chapter presented the results of the study. These results included qualitative, quantitative, and mixed-methods findings. In the qualitative section, the analysis included an analysis of open-ended questions, classroom observations, and documents analysis. The quantitative section presented a descriptive analysis of demographical information and screening procedures, including factor analysis, scale reliability, an independent t-test, and one-way ANOVA analysis. Next was the primary analysis, which included MANOVA analysis and a correlation test. In the mixed-methods section, the analysis included the convergence and divergence between the two data sets. The next chapter will present the study discussion and implications.

Chapter 5 - Discussion and Implications

The goal of this study was to explore the factors that influence in-service elementary teachers' EDI as related to science content integration and developing students' science conceptual understanding. Open-ended questions, classroom observations, and documents analysis were utilized to qualitatively explore the factors influencing the integration of science content and students' science conceptual understanding during EDI. Also, the study continued to quantitatively investigate the impact of teachers' academic preparation, degree level, professional development, and engineering design teaching experience, self-efficacy, and beliefs on science content integration and students' science conceptual understanding during EDI. The quantitative data were obtained by distributing an online cross-sectional survey to 222 elementary in-service teachers in the state of Kansas. Qualitative data and quantitative data were analyzed, examined for convergence, and utilized to answer the six research questions. This chapter discusses the study problem, findings, implementations, and limitations, and future research.

Overview of the Problem

This study was conducted to investigate the factors influencing science content integration and students' science conceptual understanding during EDI. After the implementation of NGSS in 2013, science and engineering practices become equally and officially adopted at elementary schools (K. Harris et al., 2017). It was argued that any engineering design project should address one or two science concepts (Dankenbring, Capobianco, & Eichinger, 2014). The NRC (2012) states, "Engineering and technology provide a context in which students can test their own developing scientific knowledge and apply it to practical problems; doing so enhances their understanding of science" (p. 12). However, previous studies reveal mixed results in terms of the influence of the EDI on students' science conceptual understanding. Researchers found that both teachers and students faced difficulties using EDI as context to improve students' science conceptual understanding. (Capobianco, 2011; Carlsen, 1998; Crismond, 2001). Also, recent studies revealed teachers face difficulties transitioning to NGSS-aligned curricula. (Marulcu & Barnett, 2016; Guzey, Harwell, Moreno, Peralta, & Moore, 2017). Therefore, this study was conducted to investigate the factors that influence science content integration and students' science conceptual understanding during EDI. The overarching theory of this study is the social cognitive theory, which assumes that experienced and academically prepared teachers with high self-efficacy who have positive beliefs toward elementary EDI will integrate science content into their EDI, which influences students' science conceptual understanding.

Finally, understanding the factors that influence science content integration and students' science conceptual understanding during EDI would help policymakers and universities provide schools with the needed support for teachers to design and implement NGSS-aligned engineering curricula effectively.

Summary of Findings

This mixed-methods study investigated factors influencing science content integration and students' science conceptual understanding during EDI. This section includes a discussion of the major findings as related to the literature on teacher experience, academic preparation, professional development, self-efficacy, and beliefs. A summary of the findings is presented in the following section.

Teachers' Experience

The results reveal elementary in-service teachers in the state of Kansas have different experiences in teaching engineering design. Many indicated that they never taught engineering design in their classrooms. This was an unexpected result since the NGSS was officially adopted by the state in 2013 (K. Harris et al., 2017). The findings reveal that schools' priorities, which determine the availability of time and resources, are the main factors that influence the adoption of engineering design. A participant stated, "It takes a lot of prep to prepare, and materials are not provided by district". Moreover, the quantitative results reveal that a lack of time is reported by 64.6% to be a strong or very strong barrier. These findings are consistent with previous research (Haag & Megowan, 2015; Shernoff et al., 2017; Smith & Nadelson, 2017; Stephenson, 2017; Wang, Moore, Roehrig, & Park, 2011), that reveal that the lack of time and resources are barriers to implementing engineering design.

Also, the results reveal that teachers became interested in integrating engineering design after they learned about it. This result is broadly in line with Banduras' theory (1989), "Reciprocal causation, behavior, cognition and other personal factors, and environmental influences all operate as interacting determinants that influence each other bidirectionally" (p. 2). Another findings showed that when teachers transitioned to implementing engineering design in their classrooms, they experienced difficulties and struggle during their first years of teaching engineering design. A participant stated, "trial and errors" to describe their first experience of teaching engineering design. This result concurs with Van Driel, Verloop, and de Vos's (1998) study, which indicates that when teachers teach unfamiliar topics, they face difficulties dealing with new potential issues and struggle with selecting an appropriate presentation for the subject matter.

Regarding the integration of science content into EDI, the results revealed that curriculum limitations and EDI's alignment with the NGSS are the factors that influence science content integration. This result was consistent with the literature that discusses the impact of the quality of engineering design activities. Bethke, Wendell and Rogers (2013), and Guzey et al. (2017), argued that curricula developed entirely to integrate engineering design addressed science content more effectively than simply adding engineering activities to an already-existing science unit. Furthermore, engineering design was considered by some teachers as an additional task voluntarily added to the primary science lesson. A participant indicated, “Usually the science content takes the lead and the engineering design process is not the main focal point”. However, the findings revealed that teachers experienced in teaching engineering design tended to align their instruction with the NGSS, which confirmed Haag and Megowan's (2015) findings.

The quantitative data revealed that the relationship between teachers' experience and science content integration and students' science conceptual understanding was found to be significant ($p = .023$). This result is consistent with other researchers who found a relationship between teachers' experience and the effectiveness of teacher instructional practices (Boyd, Lankford, Loeb, Rockoff, & Wyckoff, 2008; D. N. Harris & Sass, 2011; Kraft & Papay, 2014; Ost, 2014; Wiswall, 2013). Furthermore, this study found a difference between participants who never taught engineering design and participants who had three to five years of experience on science content integration and students' science conceptual understanding; however, there was no difference between participants who never taught engineering design and participants who have more than five years of experience. A possible interpretation is that some participants entered their total years of teaching experience in general, not their years of experience in teaching engineering design when they answered the online survey. For, example, a participant indicated that she has 30 years of teaching experience in general and 30 years of experience in teaching engineering design, which may not be possible.

Academic preparation

The results indicated that participants did not find their academic preparation to be effective in preparing them to teach engineering design. However, their responses emphasized the importance of including engineering design in science methods courses, by indicating they need to learn practical strategies in how to implement it in their classrooms. This result is consistent with the literature. Baker, Yasar-Purzer, Kurpius, and Krause (2007), indicated that teachers “need support in seeing how DET already exists in their own curriculum" (p. 891). In this study, participants who indicated that they had taken engineering design in science methods courses revealed a positive impact. A participant stated, “My undergraduate studies prepared me for teaching engineering design by teaching me the basics of engineering first and then teaching me how to integrate that into a classroom setting”.

The quantitative data indicate that teacher academic preparations did not influence science content integration or students' science conceptual understanding, (p = .377). Also, the degree level did not affect the two dependent variables, (p = .862). A possible explanation for not finding an influence from teachers' academic preparation and degree level is that the number of participants who indicated that they had taken engineering design courses during their undergraduate or graduate studies is small (N = 13). In addition, the study was not designed to identify participants who experienced engineering courses during a science method course or those who had taken an engineering course. This may have contributed to not finding any significant impact of teachers' preparation on the science content integration and students’ science conceptual understanding, causing the results between the qualitative and quantitative data to become inconsistent.

Professional Development

The NRC (2012*)* indicated that professional development is necessary to help in-service teachers design and implement the curriculum as desired. The findings of this study revealed that participants who reported that they had attended professional development believed that attending professional development changed their perception. They become more motivated to teach engineering design in their classrooms. This finding is in line with Banduras' theory (1989) and the literature. Haag and Megowan (2015) indicated that teacher perceptions were found to be positively changed as the teacher became more familiar with and trained to implement engineering design. Another impact of attending professional development reported by teachers is that it provided them with resources. A participant stated, "It gave me lots of ideas and resources to use when teaching engineering design". A possible interpretation is that lack of resources is a major issue facing many in-service teachers, which led them to highlight the importance of the resources provided from the professional development. The lack of resources is highlighted by researchers (Haag & Megowan, 2015; Shernoff et al., 2017; Smith & Nadelson, 2017; Stephenson, 2017; Wang, Moore, Roehrig, & Park, 2011).

Also, the results indicate that the influence of professional development on teachers' EDI depends on the quality of the professional development. An introduction to EDI did not impact teachers' EDI positively compared to systemic professional development. These results are consistent to some extent with findings from Garet et al. (2001), which suggest that any professional development that provides active learning, focuses on a specific subject matter, and integrates these training throughout the school year is more likely to be effective. Also, the study revealed that teachers who reported that they have attended professional development beyond the introductory level tended to emphasize the positive influence on their EDI, which aligns with a finding from Tuttle et al. (2016), which revealed that two weeks of professional development designed to help in-service teachers design and implement lessons aligned to the NGSS significantly improved teachers' knowledge and practices.

The quantitative results indicate that professional development influences the integration of science content and students’ science conceptual understanding, ($p < .001$), which confirmed similar results that found professional development influenced teachers’ instructional practices and students’ learning outcomes (Blank et al., 2007; Garet, Porter, Desimone, & Birman, 2001; Wei et al., 2009; Wenglinsky, 2000). Furthermore, the results indicate that there is a significant difference between participants who never attended professional development and participants who spent more than 15 hours on the integration of science content and students' science conceptual understanding, ($p = .017$). However, the results did not find significant differences between participants who never attended professional development and participants who spent less than six hours on the two dependent variables. This finding is consistent with the findings from the qualitative data, which suggests that introductory professional development about engineering design does not necessarily impact teachers’ EDI.

Self-Efficacy of Teaching Engineering Design

The results reveal three levels of self-efficacy of teaching engineering design, including fully prepared, prepared with limitations, and unprepared. Also, the results reveal that teachers’ knowledge and experience are the factors that influenced their level of self-efficacy. This result aligned with Bandura's (1989) theory that suggests that mastery experience is one of four sources of self-efficacy.

Fully prepared teachers reported that training workshops and the availability of materials helped them become fully prepared, as a participant stated, "I feel very prepared to teach engineering design through the PLTW curriculum. The training and materials provided help me teach K-6 students about the engineering design process at age-appropriate levels". Some participants revealed a limitation to their self-efficacy, which was that they could not design their own engineering design lesson, but they could carry out a lesson developed by others. A participant stated, “If I had a detailed plan, I would feel comfortable teaching it.” This result suggests that teachers with limited self-efficacy tended to search for ready-made lessons, which might explain why there are many participants who revealed that they needed resources. Also, the results reveal that teachers who feel unprepared to teach engineering design indicated that the lack of experience and knowledge prevented them from being prepared, which is consistent with Bandura’s theory (1989).

The quantitative results reveal that there is a relationship between teachers' self-efficacy and science content integration, (p = .002) and students’ science conceptual understanding (p = .002). This result is broadly in line with findings from other researchers (Britner & Pajares, 2006; Coladarci, 1992; Posnanski, 2002) who find a relationship between teachers’ self-efficacy and their instructional practices.

Beliefs About Teaching Engineering Design

The findings indicate that many participants showed strong positive beliefs about the importance of teaching engineering design. This result is consistent with the literature, which reveals that in-service teachers value EDI (Hsu, Purzer, & Cardella, 2011; Rich et al., 2017; Trygstad et al., 2013; Yoon et al., 2014). Teachers revealed two different opinions on why engineering design should be included in K-6. Some believed that engineering design has the potential to provide an exciting experience to students while others believed that it helps student learn essential skills. A similar result was confirmed by Lesseig, Nelson, Slavit, and Seidel (2016), who found that teachers believe STEM design challenges can increase students' science conceptual understanding. Another finding reveals that teachers change their perception after they have experience in teaching engineering design, which is consistent with Haag and Megowan (2015). In addition, the results indicate that participants who concurrently integrate science and engineering into their lessons believe EDI has a positive impact on students’ science achievement.

Furthermore, the results reveal some participants had neutral beliefs or tended to discuss the difficulties of including engineering design in elementary schools. Grade level taught and schools’ priorities were found to influence teachers' beliefs. Teachers at lower grade levels tended to emphasize the difficulties of integrating engineering design at their grade level due to the lack of time and access to appropriate grade-level curricula. This result is similar to Haag and Megowan's (2015) findings that indicated that high school teachers are more motivated and prepared to implement SEPs compared to middle school teachers. In addition, school priorities were found to determine how engineering design should be implemented. A teacher stated, “I honestly have never seen it. In fourth grade, we do not state test in science, so it tends to be put aside.” This may suggest that schools tend to focus on the state test, which might explain why there are not many schools adopting the NGSS across all elementary grade levels.

The quantitative results failed to find any significant relationship between teachers’ beliefs and science content integration (p = .229) or students' science conceptual understanding (p =.245). A possible interpretation for not finding a significant relationship is that most participants revealed a strong positive belief toward engineering design but many of them did not have the knowledge, experience, time, and resources needed to integrate engineering design. Also, the number of teachers who are trained and have experience in integrating engineering design is very small, which was not sufficient to detect any significant relationship between the beliefs and science content integration and students' science conceptual understanding.

Implications

The results reveal that teachers are highly motivated to include engineering design in K-6. However, 22.1% of participants reported that they do not integrate engineering design in their classrooms. The lack of time, knowledge, and resources were factors preventing them from teaching engineering design. This suggests that a decision at the school or district level should be made to provide training, time, and resources to all in-service elementary science teachers.

Also, 28.5% of participants reported that they never attended professional development workshops about teaching engineering design. Therefore, this study suggests that in-service teachers should have access to professional development workshops. Providing professional development has the potential to change teachers’ perceptions toward engineering design. As a participant stated, “PD gets me excited to try new STEM projects in my classroom! I love learning about the new ideas presented in professional development." Also, schools should be aware of the influence of introductory workshops about teaching engineering design and a systemic training program. As found in the study, introductory professional development about teaching engineering design has the potential to change the teachers' perceptions toward engineering design; however, teachers’ EDI is more likely to be influenced by more intensive and systemic professional development workshops. The quantitative results did not find any influence of professional development workshops that take less than six hours on science content integration and students’ science conceptual understanding.

In addition, the quantitative data reveal that 64.6% of participants believe that time is a strong barrier that prevents them from teaching engineering design. Also, the qualitative data reveal that a busy schedule and lack of time were reported by many teachers as limits on their ability to teach engineering design or integrate science content in EDI. Therefore, allocating time for teachers to integrate engineering design would encourage them to implement it in their classrooms and positively influence their perceptions and instructional practices.

Finally, the lack of resources is a common issue reported by participants. The study findings concluded that resources tend to determine the quality of EDI. Participants conduct their own research looking for engineering design lessons to implement in their classrooms; however, the online resources might not be aligned with NGSS. Out of four classroom observations, only one teacher facilitated EDI that aligned with NGSS. A participant indicated, "In my current curriculum, engineering design is taught alone, separate from other science content." This suggests that schools should provide curricula aligned with the NGSS to their elementary teachers, which would minimize the time teachers spend researching curricula. Also, providing the NGSS aligned curricula would minimize the chance of adopting a lesson of low quality.

This study offers suggestive evidence for universities to include engineering design in science methods courses in their pre-service teacher education programs. The findings of this study reveal the importance of engineering design in science methods courses. Pre-service teacher education programs should be designed to introduce teachers to the NGSS. Mentoring programs could provide powerful guidance to novice teachers, aiding them to develop independence in selecting, designing, and facilitating curricula aligned with NGSS.

Implications for Implementing Engineering Design in Saudi Arabia

As of October 2019, the Education and Training Evaluation Commission (ETEC) reported the performance of more than 50% of students in science was below the standard level of achievement (ETEC, 2019). Earlier, in 2018, the Ministry of Education in Saudi Arabia attempted to reform the national program to provide systemic professional development workshops for all in-service teachers in Saudi Arabia (Ministry of Education, 2018). All pre-service teacher education programs were reformed the following year (Ministry of Education, 2019). The findings of this study now reveal the critical need for implementing curricula aligned to the NGSS, which includes engineering design instruction. This research provides suggestions for policymakers in Saudi Arabia to improve the national professional development program and pre-service teaching preparation programs as follows:

1. Develop standards that include engineering as content and practice in K-6 or adopt a modified version of NGSS. The findings of this study confirmed that EDI aligned with the NGSS has a positive influence on students' science conceptual understanding.
2. Design pre-service teacher education programs to include engineering design in science methods courses. The findings in this study emphasized the positive influence of including engineering design in science methods courses on teachers’ beliefs, self-efficacy, and EDI.
3. Design professional development for science teachers to provide an opportunity for all in-service elementary teachers to learn about EDI, which will motivate them to include engineering design in their classrooms. The findings of this study reveal that professional development workshops have the potential to change teachers'

perceptions. As a participant stated, "PD gets me excited to try new STEM projects in my classroom”. Also, professional development helps teachers facilitate EDI in their classrooms. As a participant stated, “It helped me tremendously. It provided me resources, practice, and practical examples to take into my classroom”.

4. Design or adopt curricula that are aligned with the NGSS (or the new standards). Developing a curriculum that provides the rich experience that is culturally sensitive to students’ needs might be the most challenging task. The findings of this study reveal that most of the engineering design lessons observed are not aligned with NGSS. Also, the results reveal that the quality of the curriculum is a strong indicator of science content integrated with EDI and students' science conceptual understanding during EDI.
5. Provide resources, materials, and the time for teachers to teach engineering design in their classrooms. This will increase the possibility for integrating engineering design by eliminating the barriers of teaching engineering design, positively influencing teachers' beliefs, self-efficacy, and EDI as confirmed by the results of this study.

Limitations and Future Research

A limitation of this study is that it did not control for participants who did not experience engineering design during science methods courses. The qualitative data reveal the importance of including engineering design in science methods courses on the integration of science content and students' science conceptual understanding during EDI. Future studies should be designed to quantitatively capture the influence of taking engineering design during the science method courses.

Another limitation of the study is that it was not designed to identify participants who implemented a curriculum that aligned with NGSS. The researcher assumed that the NGSS was implemented in all schools across Kansas; however, the results revealed otherwise. A possible future study could be designed to investigate the influence of EDI on science content integration and students' science conceptual understanding after controlling for curricula alignment with the NGSS.

The third limitation of this study is related to the length of the survey, especially the seven open-ended questions. The number of participants’ responses to the last open-ended question was very small compared to the first open-ended question. Therefore, changing the order of the questions for participants might provide an equal opportunity for all the questions to be answered. It is possible that conducting oral interviews might help researchers collect data needed to fully eliminate the impact of variables affecting EDI.

References

Achieve. (2016). EQuIP rubric for lessons and units: Science. Retrieved from http://www.nextgenscience.org/resources/equip-rubric-lessons-units-science

Antink-Meyer, A., & Meyer, D. Z. (2016). Science teachers' misconceptions in science and engineering distinctions: Reflections on modern research examples. *Journal of Science Teacher Education*, *27*(6), 625–647. https://doi.org/10.1007/s10972-016-9478-z

Apedoe, X. S., & Schunn, C. D. (2013). Strategies for success: Uncovering what makes students successful in design and learning. *Instructional Science*, *41*(4), 773–791. https://doi.org/10.1007/s11251-012-9251-4

Appleton, K. (2003). How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice. *Research in Science Education*, *33*(1), 1–25.

Baker, D., Yasar-purzer, S., Kurpius, S. R., & Krause, S. (2007). Infusing design, engineering and technology into K-12 teachers' practice. *Engineering and Technology*, *23*(5), 884–893.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist*, *44*(9), 1175.

Bandura, A. (1994). Self-Efficacy. In V.S. Ramachaudran (Ed.). In *Encyclopedia of Human Behavior* (Vol. 4, pp. 71–81). Retrieved from https://www.uky.edu/~eushe2/Bandura/BanEncy.html

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). *Report of the 2012 national survey of science and mathematics education.* Chapel Hill, NC: Horizon Research, Inc.

Bergman, D. J., & Morphew, J. (2015). Concerns and drivers of teachers integrating engineering into classrooms. *Journal of College Science Teaching*, *44*(3), 73–81.

Bethke Wendell, K., & Rogers, C. (2013). Engineering design-based science, science content performance, and science attitudes in elementary school. *Journal of Engineering Education*, *102*(4), 513–540. https://doi.org/10.1002/jee.20026

Blank, R. K., de las Alas, N., & Smith, C. (2007). *Analysis of the quality of professional development programs for mathematics and science teachers: Findings from a cross-state study*. Washington, DC: Council of Chief State School Officers.

Bolyard, J. J., & Moyer-Packenham, P. S. (2008). A review of the literature on mathematics and science teacher quality. *Peabody Journal of Education*, *83*(4), 509–535.

Boyd, D., Lankford, H., Loeb, S., Rockoff, J., & Wyckoff, J. (2008). The narrowing gap in New York City teacher qualifications and its implications for student achievement in high-poverty schools. *Journal of Policy Analysis and Management*, *27*(4), 793–818.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485–499.

Bryan, L. A., & Atwater, M. M. (2002). Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Education*, *86*(6), 821–839.

Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education*, 211–221. https://doi.org/10.1007/s10972-014-9381-4

Carberry, A. R., Lee, H. S., & Ohland, M. W. (2010). Measuring engineering design self-efficacy. *Journal of Engineering Education*. https://doi.org/10.1002/j.2168-9830.2010.tb01043.x

Chaney, B. (1995). *Student outcomes and the professional preparation of eighth-grade teachers in science and mathematics. NSF/NELS: 88 teacher transcript analysis.* Rockville, MD: Westat.

Coladarci, T. (1992). Teachers’ sense of efficacy and commitment to teaching. *Journal of Experimental Education*, *60*(4), 323–337. https://doi.org/10.1080/00220973.1992.9943869

Creswell, J. W. (2014). *Research design: qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage Publications.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage publications.

Dare, E., Ellis, J., & Roehrig, G. (2014). Driven by beliefs: Understanding challenges physical science teachers face when integrating engineering and physics. *Journal of Pre-College Engineering Education*, *4*(2), 47–61. https://doi.org/10.7771/2157-9288.1098

Darling-Hammond, L. (2000). Teacher quality and student achievement. *Education Policy Analysis Archives*, *8*, 1–44. https://doi.org/http://dx.doi.org/10.14507/epaa.v8n1.2000

Dewey, J. (2001). *The School and Socity & The Child and Curriculum*. Mineola, NY: Dover Publications.

Diefes-Dux, H. A. (2015). Introducing engineering in elementary education: A 5-year study of teachers and students. *British Journal of Educational Technology*, *46*(5), 1015–1019. https://doi.org/10.1111/bjet.12319

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed-method surveys: The tailored design method*. Boston, MA: John Wiley.

Druva, C. A., & Anderson, R. D. (1983). Science teacher characteristics by teacher behavior and by student outcome: A meta-analysis of research. *Journal of Research in Science Teaching*, *20*(5), 467–479.

Education and Training Evaluation Commission. (2019). Education and Training Evaluation Commission reveals students' achievement in general education. Retrieved from https://www.eec.gov.sa

Engineering Design Process Models. (n.d.). Retrieved September 1, 2018, from https://www.linkengineering.org/Discover/EngineeringDesign/5824.aspx

Ferguson, P., & T. Womack, S. (1993). The impact of subject matter and on teaching performance. *Journal of Teacher Education*, *44*(1), 55–63.

Fick, S. J. (2018). What does three-dimensional teaching and learning look like?: Examining the potential for crosscutting concepts to support the development of science knowledge. *Science Education*, *102*(1), 5–35.

Friday Institute for Educational Innovation. (2012). *Teacher efficacy and beliefs toward STEM survey*. Raleigh, NC: Author.

Garcia, C. M. (2016). *Engineering design process: Creating and 3D printing a mechanical toy*. (Masters's thesis). Retrieved from http://hdl.handle.net/2152/43622

Garet, M. S., Porter, A. C., Desimone, L., & Birman, B. F. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915–945.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915–945.

George, D., & Mallery, P. (2011). *SPSS for windows step by step: A simple guide and reference. 18.0 update*. Boston, MA: Pearson Education.

Goldhaber, D. D., & Brewer, D. J. (1996). *Evaluating the effect of teacher degree level on educational performance.* Rockville, MD: Westat.

Guzey, S. S., Harwell, M., Moreno, M., Peralta, Y., & Moore, T. J. (2017). The impact of design-based STEM integration curricula on student achievement in engineering, science, and mathematics. *Journal of Science Education and Technology*, *26*(2), 207–222.

Guzey, S. S., Tank, K., Wang, H., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3-6 for implementing engineering into classrooms. *School Science and Mathematics*, *114*(3), 139–149. https://doi.org/10.1111/ssm.12061

Haag, S., & Megowan, C. (2015). Next generation science standards: A national mixed-methods study on teacher readiness. *School Science and Mathematics*, *115*(8), 416–426. https://doi.org/10.1111/ssm.12145

Hammack Rebekah, R., & Ivey, T. (2017). Examining elementary teachers' engineering self-efficacy and engineering teacher efficacy. *School Science & Mathematics*, *117*(1/2), 52–62.

Haney, J. J., Czerniak, C. M., & Lumpe, A. T. (1996). Teacher beliefs and intentions regarding the implementation of science education reform strands. *Journal of Research in Science Teaching*, *33*(9), 971–993.

Harris, D. N., & Sass, T. R. (2011). Teacher training, teacher quality and student achievement. *Journal of Public Economics*, *95*(7–8), 798–812.

Harris, K., Sithole, A., & Kibirige, J. (2017). A needs assessment for the adoption of next generation science standards (NGSS) in K-12 education in the united states. *Journal of Education and Training Studies*, *5*(9), 54. https://doi.org/10.11114/jets.v5i9.2576

Hawk, P. P., Coble, C. R., & Swanson, M. (1985). Certification: It does matter. *Journal of Teacher Education*, *36*(3), 13–15.

Hayes, K. N., Lee, C. S., DiStefano, R., O'Connor, D., & Seitz, J. C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *Journal of Science Teacher Education*, *27*(2), 137–164. https://doi.org/10.1007/s10972-016-9448-5

Hill-Cunningham, P. R., Mott, M. S., & Hunt, A. (2018). Facilitating an elementary engineering design process module. *School Science and Mathematics*, *118*(1–2), 53–60.

Hoy, A. W., & Spero, R. B. (2005). Changes in teacher efficacy during the early years of teaching: A comparison of four measures. *Teaching and Teacher Education*, *21*(4), 343–356.

Hsu, M. M., & Cardella, M. E. (2013). Engineering design process knoweldge: Comparison between teachers new to engineering and more experienced teachers. In *120th American Society for Engineering Education Annual Conference and Exposition*. Atlanta, GA.

Hsu, M., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 31–39.

Kim, J. H. (2016). *Understanding narrative inquiry: The crafting and analysis of stories as research*. Los Angeles, CA: Sage publications.

Kraft, M. A., & Papay, J. P. (2014). Can professional environments in schools promote teacher development? Explaining heterogeneity in returns to teaching experience. *Educational Evaluation and Policy Analysis*, *36*(4), 476–500.

Laczko-Kerr, I., & Berliner, D. C. (2002). The effectiveness of "Teach for America" and other under-certified teachers. *Education Policy Analysis Archives*, *10*, 1–53. https://doi.org/10.14507/epaa.v10n37.2002

LaTurner, R. J. (2002). Teachers' academic preparation and commitment to teach math and science. *Teaching and Teacher Education*, *18*(6), 653–663.

Lee, J., & Strobel, J. (2014). Concerns and drivers of teachers integrating engineering into classrooms. In M. Purzer, S. Strobel, J. Cardella (Ed.), *Engineering in pre-college settings:*

synthesizing research, policy, and practices. Purdue University Press.

Lesseig, K., Nelson, T. H., Slavit, D., & Seidel, R. A. (2016). Supporting middle school teachers' implementation of STEM design challenges. *School Science and Mathematics*, *116*(4), 177–188.

Levin, K. A. (2006). Study design III: Cross-sectional studies. *Evidence-Based Dentistry*, *7*(1), 24–25.

Macalalag, A., Lowes, S., McKay, M., Guo, K., & McGrath, E. (2009). Promoting scientific inquiry through innovative science and engineering curricula in grades 3 5. In *American Society for Engineering Education Annual Conference*. Austin, TX.

Marquis, S. D. (2015). *Investigating the influence of professional development on teacher perceptions of engineering self-efficacy*. (doctoral dissertation). Retrieved from https://digitalcommons.usm.maine.edu/cgi/viewcontent.cgi?article=1128&context=etd

Marshall, J. C., Smart, J., & Horton, R. M. (2010). The design and validation of EQUIP: An instrument to assess inquiry-based instruction. *International Journal of Science and Mathematics Education*, *8*(2), 299–321.

Marshall, J. C., Smart, J., Lotter, C., & Sirbu, C. (2011). Comparative analysis of two inquiry observational protocols: Striving to better understand the quality of teacher-facilitated inquiry-based instruction. *School Science and Mathematics*, *111*(6), 306–315.

Matthews, M. E. (2013). The influence of the pedagogical content knowledge framework on research in mathematics education: A review across grade bands. *Journal of Education*, *193*(3), 29–37.

McDermott, L. C. (1990). A perspective on teacher preparation in physics and other sciences: The need for special science courses for teachers. *American Journal of Physics*, *58*(8), 734–

742.

Mecol, S. (2013). The influence of the pedagogical content knowledge theoretical framework on research on preservice teacher education. *Journal of Education,* (193(3)), 21–27.

Ministry of Education. (2018). The national center For teacher professional development. Retrieved from https://ncepd.moe.gov.sa/ar/Pages/default.aspx

Ministry of Education. (2019). Improving pre-service teachers education programs. Retrieved from https://departments.moe.gov.sa/PlanningDevelopment/RelatedDepartments/committee/Pages/default.aspx

National Research Council. (2012). *A Framework for K-12 Science Education*. *A Framework for K-12 Science Education: Practices, Croscutting Concepts, and Core Ideas.* Washington, DC: National Academies Press. https://doi.org/10.17226/13165

National Research Council. (2013). *Next generation science standards : For states, by states*. Washington, D.C: National Academies Press. https://doi.org/https://doi.org/10.17226/18290

Ost, B. (2014). How do teachers improve? The relative importance of specific and general human capital. *American Economic Journal: Applied Economics*, *6*(2), 127–151.

Pajares, M. F. (1992). Teachers’ beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307–332.

Posnanski, T. J. (2002). Professional development programs for elementary science teachers: An analysis of teacher self-efficacy beliefs and a professional development model. *Journal of Science Teacher Education*, *13*(3), 189–220.

Pruitt, S. L. (2015). The next generation science standards. *The Science Teacher*, *82*(5), 17.

Quigley, C., Marshall, J. C., & Deaton, C. (2011). Challenges to inquiry teaching and suggestions for how to meet them. *Science Educator*, *20*(1), 55–61.

Ramey-Gassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self-efficacy of elementary level teachers. *Science Education*, *80*(3), 283–315.

Rich, Peter J, Jones, E., Shumway, S. L., & Anderson, N. E. (2018). Development of a Tool to Measure Teachers' Beliefs and Self-Efficacy in Elementary Engineering (BSEEE-T). *Unpublished*. https://doi.org/10.13140/RG.2.2.11918.87362

Rich, Peter Jacob, Jones, B., Belikov, O., Yoshikawa, E., & Perkins, M. (2017). Computing and engineering in elementary school: The effect of year-Long training on elementary teacher self-efficacy and beliefs about teaching computing and engineering. *International Journal of Computer Science Education in Schools*, *1*(1). https://doi.org/https://doi.org/10.21585/ijcses.v1i1.6

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, *74*(6), 625–637.

Saldaña, J. (2013). *The Coding Manual for Qualitative Researchers (2nd Ed.)*. *SAGE Publications Inc.* https://doi.org/10.1017/CBO9781107415324.004

Schnittka, C., & Bell, R. (2011). Engineering design and conceptual change in science: Addressing thermal energy and heat transfer in eighth grade. *International Journal of Science Education*, *33*(13), 1861–1887. https://doi.org/10.1080/09500693.2010.529177

Schnittka, C., Turner, G. E., & Colvin, R. W. (2014). A state wide professional development program in engineering with science and math teachers in Alabama: Fostering conceptual understandings of STEM. *121st ASEE Annual Conference & Exposition*.

Shernoff, D. J., Sinha, S., Bressler, D. M., & Schultz, D. (2017). Teacher perceptions of their curricular and pedagogical shifts: Outcomes of a project-based model of teacher professional development in the next generation science standards. *Frontiers in Psychology*, *8*(989), 1–16.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1–23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Smith, J., & Nadelson, L. (2017). Finding alignment: The perceptions and integration of the next generation science standards practices by elementary teachers. *School Science and Mathematics*, *117*(5), 194–203.

Stephenson, R. L. (2017). *Elementary teachers' perceptions of teaching science to improve student content knowledge*. (doctoral dissertation). Retrieved from https://scholarworks.waldenu.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=4943&context=dissertations

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Procedures and techniques for developing grounded theory*. Sage Publications.

Tavakol, M., & Dennick, R. (2011). Making sense of cronbach's alpha. *International Journal of Medical Education*, *2*, 53.

Telese, J. A. (2008). Teacher professional development in mathematics and student achievement: A NAEP 2005 analysis. In *Paper presented at the Annual Meeting of the School Science and Mathematics Association*. Raleigh, NC.

Trygstad, P. J., Smith, P. S., Banilower, E. R., & Nelson, M. M. (2013). *The status of elementary science education: Are we ready for the next generation science standards? Horizon Research, Inc.* Chapel Hill, NC. Retrieved from http://eric.ed.gov/?id=ED548249

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, *23*(6), 944–956.

Tuttle, N., Kaderavek, J. N., Molitor, S., Czerniak, C. M., Johnson-Whitt, E., Bloomquist, D., … Wilson, G. (2016). Investigating the impact of NGSS-aligned professional development on PreK-3 teachers' science content knowledge and pedagogy. *Journal of Science Teacher Education*, *27*(7), 717–745.

Van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, *35*(6), 673–695.

Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 1–13.

Wei, R. C., Darling-Hammond, L., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the US and abroad. Technical report.* Dallas, TX: National Staff Development Council.

Weinfurt, K. P. (1995). Multivariate analysis of variance. In L. G. Grimm & P. R. Yarnold (Ed.), *Reading and understanding multivariate statistics* (pp. 245–276). Washington, DC: American Psychological Association.

Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality.* Princeton, NY: Milken Family Foundation and Educational Testing Service.

Wiswall, M. (2013). The dynamics of teacher quality. *Journal of Public Economics*, *100*, 61–78.

Yasar, Se., Baker, D., Robinson-Kurpius, S., Krause, S., & Roberts, C. (2006). Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology. *Journal of Engineering Education*, *95*(3), 205–216.

https://doi.org/10.1002/j.2168-9830.2006.tb00893.x

Yoon, S. Y., Diefes-Dux, H., & Strobel, J. (2013). First-year effects of an engineering professional development program on elementary teachers. *American Journal of Engineering Education*, *4*(1), 67–84.

Yoon, S. Y., Dyehouse, M., Lucietto, A. M., Diefes-Dux, H. A., & Capobianco, B. M. (2014). The effects of integrated science, technology, and engineering education on elementary students' knowledge and identity development. *School Science and Mathematics*, *114*(8), 380–391. https://doi.org/10.1111/ssm.12090

Appendix A - The Survey

Experience

1- How many years have you taught prior to this school year: [Enter each response as a whole number]?
   a) Any subject at the K–6 level? ______
   b) Science at the K–6 level? ______
   c) Engineering Design at the K–6 levels? ______

2- At what grade levels do you currently teach science? Select all that apply
   a) Kindergarten
   b) 1
   c) 2
   d) 3
   e) 4
   f) 5
   g) 6
   h) You do not currently teach science

3- How often do you teach engineering design in your classroom?
   a) Never
   b) A few times a year
   c) Once or twice a month
   d) Once or twice a week
   e) Daily or almost daily
   f) Other, please specify______

4- Please describe how your past teaching experience has influenced or not influenced your engineering design instruction.
   ____
   ____
   ____
   ____

Teachers' Academic Preparation

5- Have you been awarded one or more bachelor's and/or graduate degrees in the following fields? (With regard to bachelor's degrees, count only areas in which you majored.)
   a) Education, including science education
   b) Natural Sciences and/or Engineering
   c) Other, please specify____

6- What type of education degree do you have? (With regard to bachelor's degrees, count only areas in which you majored.) [Presented only to teachers that answered "Yes" to Q5 a]

	Yes	No
a) Elementary Education	☐	☐
b) Mathematics Education	☐	☐
c) Science Education	☐	☐
d) Other Education, please specify_______	☐	☐

7- What type of natural science and/or engineering degree do you have? (With regard to bachelor's degrees, count only areas in which you majored.) [Presented only to teachers that answered "Yes" to Q5b]
   a) Biology/Life Science
   b) Chemistry
   c) Earth/Space Science
   d) Engineering
   e) Environmental Science/Ecology
   f) Physics
   g) Other natural science, please specify

8- Did you complete any of the following types of biology/life science courses at the undergraduate or graduate level?

	Yes	No
a) General/introductory biology/life science courses (for example: Biology I, Introduction to Biology	☐	☐
b) Biology/life science courses beyond the general/introductory level	☐	☐
c) Biology/life science education courses	☐	☐

9- Did you complete any of the following types of chemistry courses at the undergraduate or graduate level?

	Yes	No
a) General/introductory chemistry courses (for example: Chemistry I, Introduction to Chemistry)	☐	☐
b) Chemistry courses beyond the general/introductory level	☐	☐
c) Chemistry education courses	☐	☐

10- Did you complete any of the following types of physics courses at the undergraduate or graduate level?

	Yes	No
a) General/introductory physics courses (for example: Physics I, Introduction to Physics)	☐	☐
b) Physics courses beyond the general/introductory level	☐	☐
c) Physics education courses	☐	☐

11- Did you complete any of the following types of Earth/space science courses at the undergraduate or graduate level?

	Yes	No
a) General/introductory Earth/space science courses (for example: Earth Science I, Introduction to Earth Science)	☐	☐
b) Earth/space science courses beyond the general/introductory level	☐	☐
c) Earth/space science education courses	☐	☐

12- Did you complete any of the following types of environmental science courses at the undergraduate or graduate level?

	Yes	No
a) General/introductory environmental science courses (for example: Environmental Science I, Introduction to Environmental Science)	☐	☐
b) Environmental science courses beyond the general/introductory level	☐	☐
c) Environmental science education courses	☐	☐

13- Did you complete one or more engineering courses at the undergraduate or graduate level?
   a) Yes
   b) No} skip to 15

14- Please indicate which of the following types of engineering courses you completed at the undergraduate or graduate level [Presented only to teachers that answered "Yes" to Q13]
   a) Aerospace Engineering
   b) Electrical Engineering
   c) Bioengineering/Biomedical Engineering
   d) Industrial/Manufacturing Engineering
   e) Chemical Engineering
   f) Mechanical Engineering
   g) Civil Engineering
   h) Computer Engineering
   i) Other types of engineering courses
   j)

15- Please indicate the highest degree you hold?
   a) Bachelor's degree
   b) Master's degree
   c) Doctorate degree
   d) Other________

16- In your own words, explain if your undergraduate and/or graduate studies prepared or did not prepare you to teach engineering design?

____

____

____

Professional Development

17- What is the total amount of time you have spent on professional development in engineering or engineering teaching in the last 3 years? (Include attendance at professional meetings, workshops, and conferences, as well as professional learning communities/lesson studies/teacher study groups. Do not include formal courses for which you received college credit or time you spent providing professional development for other teachers.)
   a) Never
   b) Less than 6 hours
   c) 6–15 hours
   d) 16–35 hours
   e) More than 35 hours

18- Please describe how your professional development did or did not affect your engineering design instruction

____

____

____

Barriers to Teach Engineering Design

How strong is each of the following a BARRIER in integrating engineering in your classroom? (1 = not strong at all, 5 = very strong)

19- Barrier in integrating engineering - lack of teacher knowledge	1	2	3	4	5
20- Barrier in integrating engineering - lack of training	1	2	3	4	5
21- Barrier in integrating engineering - lack of administrative support	1	2	3	4	5
22- Barrier in integrating engineering - lack of time for teachers to learn about engineering	1	2	3	4	5
23- Barrier in integrating engineering – lack of teaching experience in engaging diverse learners	1	2	3	4	5

Beliefs

Please respond to these questions regarding your feelings about ***your own*** teaching (1 = strongly agree, 6 = strongly disagree)

24- Engineering content and principles can be understood by elementary school children.	1	2	3	4	5	6
25- Learning about engineering can help elementary students become more engaged in school.	1	2	3	4	5	6

26- Engineering concepts should be taught to elementary school students.	1	2	3	4	5	6
27- Engineering is a 21st-century skill that is as important as "the basics" (Reading, Writing, Arithmetic).	1	2	3	4	5	6
28- Providing more in-class engineering activities would enrich the overall learning of my students.	1	2	3	4	5	6
29- Engineering content is an important part of the new science standards.	1	2	3	4	5	6
30- Engineering concepts should be taught much more frequently in elementary school.	1	2	3	4	5	6

31- What were your initial views/feelings about the inclusion of engineering design in the NGSS for grade K-6?

Self-efficacy

Please respond to these questions regarding your feelings about ***your own*** teaching

(1 = strongly agree, 6 = strongly disagree)

32- I believe that I have the requisite science skills to integrate engineering content into my class lessons.	1	2	3	4	5	6
33- I can recognize and appreciate the engineering concepts in all subject areas.	1	2	3	4	5	6
34- I can describe the process of engineering design.	1	2	3	4	5	6
35- I believe that I have the requisite math skills to integrate engineering content into my class lessons.	1	2	3	4	5	6

36- I can create engineering activities at the appropriate level for my students.	1	2	3	4	5	6

37- Please describe how prepared or unprepared do you feel to teach engineering design.

____

____

____

Science Content Integration

How often do you do each of the following in your engineering design instruction?	Never	Rarely (a few times a year)	Sometimes (once or twice a month)	Often (once or twice a week)	Daily or almost daily
38- Provide direct instruction to explain science concepts	1	2	3	4	5
39- Use activity sheets to reinforce skills or content	1	2	3	4	5
40- Go over science vocabulary	1	2	3	4	5
41- Apply science concepts to explain natural events or real-world situations	1	2	3	4	5
42- Talk with your students about things they do at home that are similar to what is done in science class (e.g., measuring, boiling water)	1	2	3	4	5

43- Discuss students’ prior knowledge or experience related to the science topic or concept	1	2	3	4	5
44- Encourage students to explain concepts to one another	1	2	3	4	5

45- Please describe how science content is integrated during your engineering design instruction.

Students’ Science Conceptual Understanding

How often do your students do each of the following in your engineering design instruction?	Never	Rarely (a few times a year)	Sometimes (once or twice a month)	Often (once or twice a week)	Daily or almost daily
46- Identify questions from observations of phenomena	1	2	3	4	5
47- Write about what was observed and why it happened	1	2	3	4	5
48- Create a physical model of a scientific phenomenon (like creating a representation of the solar system)	1	2	3	4	5

49- Explain the reasoning behind an idea	1	2	3	4	5
50- Create reasonable explanations of results of an experiment or investigation.	1	2	3	4	5
51- Engage in content-driven dialogue.	1	2	3	4	5

52- Please explain how effective or ineffective did you find engineering design to teach science content for your students.

____

____

____

Demographic information

53- Please indicate your gender:

a) Male
b) Female
c) _____

54- Please indicate your ethnicity/race:

a) American Indian or Alaska Native
b) Asian
c) Black or African American
d) Hispanic or Latino
e) Native Hawaiian or Pacific Islander
f) White
g) _____

55- Please use the drop-down menu to select the county where you teach.

56- Is the school you currently work for Title I eligible: Yes____ No____?

57- What curriculum/materials do you use to teach engineering design? (For example, FOSS)

58- Dear elementary teacher,

If you would like to participate in the second phase of my study, which includes one classroom (lesson) observation and one lesson plan review, please provide your contact information.

Name :

Email

Appendix B - EQuIP Rubric for Lessons & Units

EQuIP Rubric for Lessons & Units: Science

Version 3.0

Introduction:

The Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for science provides criteria by which to measure the alignment and overall quality of lessons and units with respect to the Next Generation Science Standards (NGSS). The purposes of the rubric and review process are to: (1) review existing lessons and units to determine what revisions are needed; (2) provide constructive criterion-based feedback and suggestions for improvement to developers; (3) identify exemplars/models for teachers' use within and across states; and (4) to inform the development of new lessons and units.

To effectively apply this rubric, an understanding of the National Research Council's *A Framework for K–12 Science Education and the Next Generation Science Standards*, including the NGSS shifts (Appendix A of the NGSS), is needed. Unlike in the EQuIP Rubrics for mathematics and ELA, there is not a category in the science rubric for shifts. Over the course of the rubric development, writers and reviewers noted that the shifts fit naturally into the other three categories. For example, the blending of the three-dimensions, or three-dimensional learning, is addressed in each of the three categories; coherence is addressed in the first two categories; connections to the Common Core State Standards is addressed in the first category; etc. Each category includes criteria by which to evaluate the integration of engineering, when included in a lesson or unit, through practices or disciplinary core ideas. Another difference between the EQuIP Rubrics from mathematics and ELA is in the name of the categories; the rubric for science refers to them simply as *categories*, whereas the math and ELA rubrics refer to the categories as dimensions. This distinction was made because the Next Generation Science Standards already uses the term *dimensions* to refer to practices, disciplinary core ideas, and crosscutting concepts.

The architecture of the NGSS is significantly different from other sets of standards. The three dimensions, crafted into performance expectations, describe what is to be assessed following instruction and therefore are the measure of proficiency. A lesson or unit may provide opportunities for students to demonstrate performance of practices connected with their understanding of core ideas and crosscutting concepts as foundational pieces. This three-dimensional learning leads toward eventual mastery of performance expectations. In this scenario, quality materials should clearly describe or show how the lesson or unit works coherently with previous and following lessons or units to help build toward eventual mastery of performance expectations. The term *element* is used in the rubric to represent the relevant, bulleted practices, disciplinary core ideas, and crosscutting concepts that are articulated in the foundation boxes of the standards and in K–12 grade-banded progressions and the NGSS Appendices. Given the understanding that lessons and units should integrate the practices, disciplinary core ideas, and crosscutting concepts in ways that make sense instructionally and not replicate the exact integration in the performance expectations, the new term *elements* is needed to describe these smaller units of the three dimensions. Although it is unlikely that a single lesson would provide adequate opportunities for a student to demonstrate proficiency on an entire performance expectation, high-quality units are more likely to provide these opportunities to demonstrate proficiency on one or more performances expectations.

There is a recognition among educators that curriculum and instruction will need to shift with the adoption of the NGSS, but it is currently difficult to find instructional materials designed for the NGSS. The power of the rubric is in the feedback and suggestions for improvement it provides curriculum developers and the productive conversations in which educators engage while evaluating materials using the quality review process. For curriculum developers, the rubric and review process provide evidence of the quality and the degree to which the lesson or unit is designed for the NGSS. Additionally, the rubric and review process generate suggestions for improvement on how materials can be further improved and better designed to match up with the vison of the *Framework* and the NGSS.

Version 3.0 — published September 2016

EQuIP Rubric for Lessons & Units: Science

<u>Lessons *and* units</u> designed for the NGSS include clear and compelling evidence of the following*:*

I. NGSS 3D Design	**II. NGSS Instructional Supports**	**III. Monitoring NGSS Student Progress**
The lesson/unit is designed so students make sense of phenomena and/or design solutions to problems by engaging in student performances that integrate the three dimensions of the NGSS.	*The lesson/unit supports three-dimensional teaching and learning for ALL students by placing the lesson in a sequence of learning for all three dimensions and providing support for teachers to engage all students.*	*The lesson/unit supports monitoring student progress in all three dimensions of the NGSS as students make sense of phenomena and/or design solutions to problems.*
A. **Explaining Phenomena/Designing Solutions**: Making sense of phenomena and/or designing solutions to a problem drive student learning. i. Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving. ii. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems. iii. When engineering is a learning focus, it is integrated with developing disciplinary core ideas from physical, life, and/or earth and space sciences.	A. **Relevance and Authenticity**: Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world. i. Students experience phenomena or design problems as directly as possible (firsthand or through media representations). ii. Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate. iii. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience.	A. **Monitoring 3D student performances**: Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions.
B. **Three Dimensions**: Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions. i. Provides opportunities to *develop and use* specific elements of the SEP(s). ii. Provides opportunities to *develop and use* specific elements of the DCI(s). iii. Provides opportunities to *develop and use* specific elements of the CCC(s).	B. **Student Ideas:** Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and to respond to peer and teacher feedback orally and/or in written form as appropriate.	B. **Formative:** Embeds formative assessment processes throughout that evaluate student learning to inform instruction.
C. **Integrating the Three Dimensions:** Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.	C. **Building Progressions**: Identifies and builds on students' prior learning <u>in all three dimensions</u>, including providing the following support to teachers: i. Explicitly identifying prior student learning expected for all three dimensions ii. Clearly explaining how the prior learning will be built upon	C. **Scoring guidance**: Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.
	D. **Scientific Accuracy**: Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.	D. **Unbiased tasks/items**: Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.
	E. **Differentiated Instruction**: Provides guidance for teachers to support differentiated instruction by including: i. Appropriate reading, writing, listening, and/or speaking alternatives (e.g., translations, picture support, graphic organizers, etc.) for students who are English language learners, have special needs, or read well below the grade level. ii. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations. iii. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts.	

EQuIP Rubric for Lessons & Units: Science

Units designed for the NGSS will *also include* clear and compelling evidence of the following additional criteria:

I. NGSS 3D Design	II. NGSS Instructional Supports	III. Monitoring NGSS Student Progress
D. **Unit Coherence**: Lessons fit together to target a set of performance expectations. i. Each lesson builds on prior lessons by addressing questions raised in those lessons, cultivating new questions that build on what students figured out, or cultivating new questions from related phenomena, problems, and prior student experiences. ii. The lessons help students develop toward proficiency in a targeted set of performance expectations. E. **Multiple Science Domains**: *When appropriate*, links are made across the science domains of life science, physical science and Earth and space science. i. Disciplinary core ideas from different disciplines are used together to explain phenomena. ii. The usefulness of crosscutting concepts to make sense of phenomena or design solutions to problems *across science domains* is highlighted. F. **Math and ELA:** Provides grade-appropriate connection(s) to the Common Core State Standards in Mathematics and/or English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects.	F. **Teacher Support for Unit Coherence:** Supports teachers in facilitating coherent student learning experiences over time by: i. Providing strategies for linking student engagement across lessons (e.g. cultivating new student questions at the end of a lesson in a way that leads to future lessons, helping students connect related problems and phenomena across lessons, etc.). ii. Providing strategies for ensuring student sense-making and/or problem-solving is linked to learning in all three dimensions. G. **Scaffolded differentiation over time**: Provides supports to help students engage in the practices as needed and gradually adjusts supports over time so that students are increasingly responsible for making sense of phenomena and/or designing solutions to problems.	E. **Coherent Assessment system:** Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning. F. **Opportunity to learn**: Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback.

Using the EQuIP Rubric for Lessons & Units: Science

The first step in the review process is to become familiar with the rubric, the lesson or unit, and the practices, disciplinary core ideas, and crosscutting concepts targeted in the lesson or unit. The three categories in the rubric are: NGSS 3D Design, NGSS Instructional Supports, and Monitoring NGSS Student Progress. Each criterion within each category should be considered separately as part of the complete review process and are used to provide sufficient information for determination of overall quality of the lesson or unit.

For the purposes of using the rubric, **a lesson is defined as**: a set of instructional activities and assessments that may extend over several class periods or days; it is more than a single activity. A **unit is defined as**: a set of lessons that extend over a longer period of time. If you are reviewing a lesson, you will use only the first section of the rubric (page 2). If you are reviewing an instructional unit, you apply all of the criteria of the rubric (pages 2 and 3) across the unit. You'll notice that the definition of a "unit" is intentionally broad here. If you are reviewing instructional materials that cover more than a few days of instruction, use the full unit list of criteria.

Also important to the review process is feedback and suggestions for improvement to the developer of the resource. For this purpose, a set of response forms is included so that the reviewer can effectively provide criterion-based feedback and suggestions for improvement for each category. The response forms correspond to the criteria of the rubric. Evidence for each criterion must be identified and documented and criterion-based feedback and suggestions for improvement should be given to help improve the lesson or unit.

While it is possible for the rubric to be applied by an individual, the quality review process works best with a team of reviewers, as a collaborative process, with the individuals recording their thoughts and then discussing with other team members before finalizing their feedback and suggestions for improvement. Discussions should focus on understanding all reviewers' interpretations of the criteria and the evidence they have found. With professional learning support for the group, this process will provide higher quality feedback about the lessons and also calibrate responses across reviewers in a way that moves them toward agreement about quality with respect to the NGSS. Commentary needs to be constructive, with all lessons or units considered "works in progress." Reviewers must be respectful of team members and the resource contributor. Contributors should see the review process as an opportunity to gather feedback and suggestions for improvement rather than to advocate for their work. All feedback and suggestions for improvement should be criterion-based and have supporting evidence from the lesson or unit cited.

In order to apply the rubric with reliability and with fidelity to its intent, it is recommended that those applying the rubric to lessons and units be supported to attend EQuIP professional learning based on the EQuIP Facilitator's Guide. There is guidance within the rubric below and in the Facilitator's Guide, but application of the rubric is much more successful with the support of professional learning. It is difficult to develop proficiency at using the rubric without *at least* two days of high quality professional learning that engages participants in evaluating lessons and units.

Step 1 – Review Materials

The first step in the review process is to become familiar with the rubric and the lesson or unit that is being evaluated.

- Review the rubric and record the grade and title of the lesson or unit on the response form.
- Scan the lesson/unit to see what it's about; identify what practices, disciplinary core ideas, and crosscutting concepts are targeted; and determine how it is organized.
- Read key materials related to instruction, assessment, and teacher guidance.
- Read the definitions of "lesson" and "unit" near the top of this page and decide as a group whether you will be using the shorter list of criteria for a lesson, or the longer list of criteria that apply to a unit.

Step 2 – Apply Criteria in Category I: NGSS 3D Design

Evaluate the lesson or unit using the criteria in the first category, first individually and then as a team.

- Closely examine the lesson or unit through the "lens" of each criterion in the first category.
- For each criterion, record where you find it in the lesson/unit (the evidence) and why/how this evidence is an indicator the criterion is being met (the reasoning)
- As individuals, check the box for each criterion on the response form that indicates the degree to which evidence could be identified.
- Identify and record input on specific improvements that might be made to meet criteria or strengthen alignment.

- Look across the criteria of the category (A–C for a lesson and A–F for a unit), evaluate the degree to which they are met, and enter your 0–3 rating for Category I: NGSS 3D Design (see scale description below)
- As a team, discuss criteria for which clear and substantial evidence is found, as well as criterion-based suggestions for specific improvements that might be needed to meet criteria. As a team, enter your 0–3 rating for Dimension I: NGSS 3D Design.

*If the rubric is being used to approve or vet resources and the lesson or unit does not score at least a "2" in **Category I: NGSS 3D Designed**, the review should stop and feedback should be provided to the lesson developer(s) to guide revisions. If the rubric is being used locally for revising and building lessons, professional judgment should guide whether to continue reviewing the lesson. Categories II and III may be time consuming to evaluate if Category I has not been met and the feedback may not be useful if significant revisions are needed in Category I, but evaluating these criteria in a group may support deeper and more common understanding of the criteria in these categories and more complete feedback to the lesson developer (if they are not in the room) so that Categories II and III are more likely to be met with fewer cycles of revision.*

Step 3 – Apply Criteria in Categories II and III: Instructional Supports and Monitoring Student Progress

The third step is to evaluate the lesson or unit using the criteria in the second and third categories, first individually and then as a group.

- Closely examine the lesson or unit through the "lens" of each criterion in the second and third categories of the response form.
- For each criterion, record where you find it in the lesson/unit (the evidence) and why/how this evidence is an indicator the criterion is being met (the reasoning)
- Individually check the box for each criterion on the response form that indicates the degree to which evidence could be identified.
- Record any suggestions for improvement and then rate each category using the 0–3 rating scale in the forms below.

When working in a group, teams may choose to compare ratings after each category or delay conversation until each person has rated and recorded input for both Categories II and III. Complete consensus among team members is not required but discussion is a key component of the review process that moves the group to a better understanding of the criteria.

Step 4 – Apply an Overall Rating and Provide Summary Comments

- Review ratings for Categories I–III, adding/clarifying comments as needed.
- Write summary comments for your overall rating on your recording sheet.
- Total category ratings, reflect on the overall quality of the lesson or unit, and record the overall rating of E, E/I, R, or N.

If working in a group, individuals should record their overall rating prior to conversation.

Step 5 – Compare Overall Ratings and Recommend Next Steps

- Note the evidence cited to arrive at final ratings, summary comments and similarities and differences among raters. Recommend next steps for the lesson/unit and provide recommendations for improvement and/or ratings to developers/teachers.

Rating Scales

Rating for Category I: NGSS 3D Designed is non-negotiable and requires a rating of 2 or 3. If rating is 0 or 1 then a review for resource approval does not continue.

Rating Scale for Categories I, II, & III:

Rating scales are different for each category and can be found after each category in the rubric.

Descriptors for Categories I, II, & III:

3: **Exemplifies NGSS Quality**—meets the standard described by criteria in the category, as explained in criterion-based observations.

2: **Approaching NGSS Quality**—meets many criteria but will benefit from revision in others, as suggested in criterion-based observations.

1: **Developing toward NGSS Quality**—needs significant revision, as suggested in criterion-based observations.

0: **Not representing NGSS Quality**—does not address the criteria in the category.

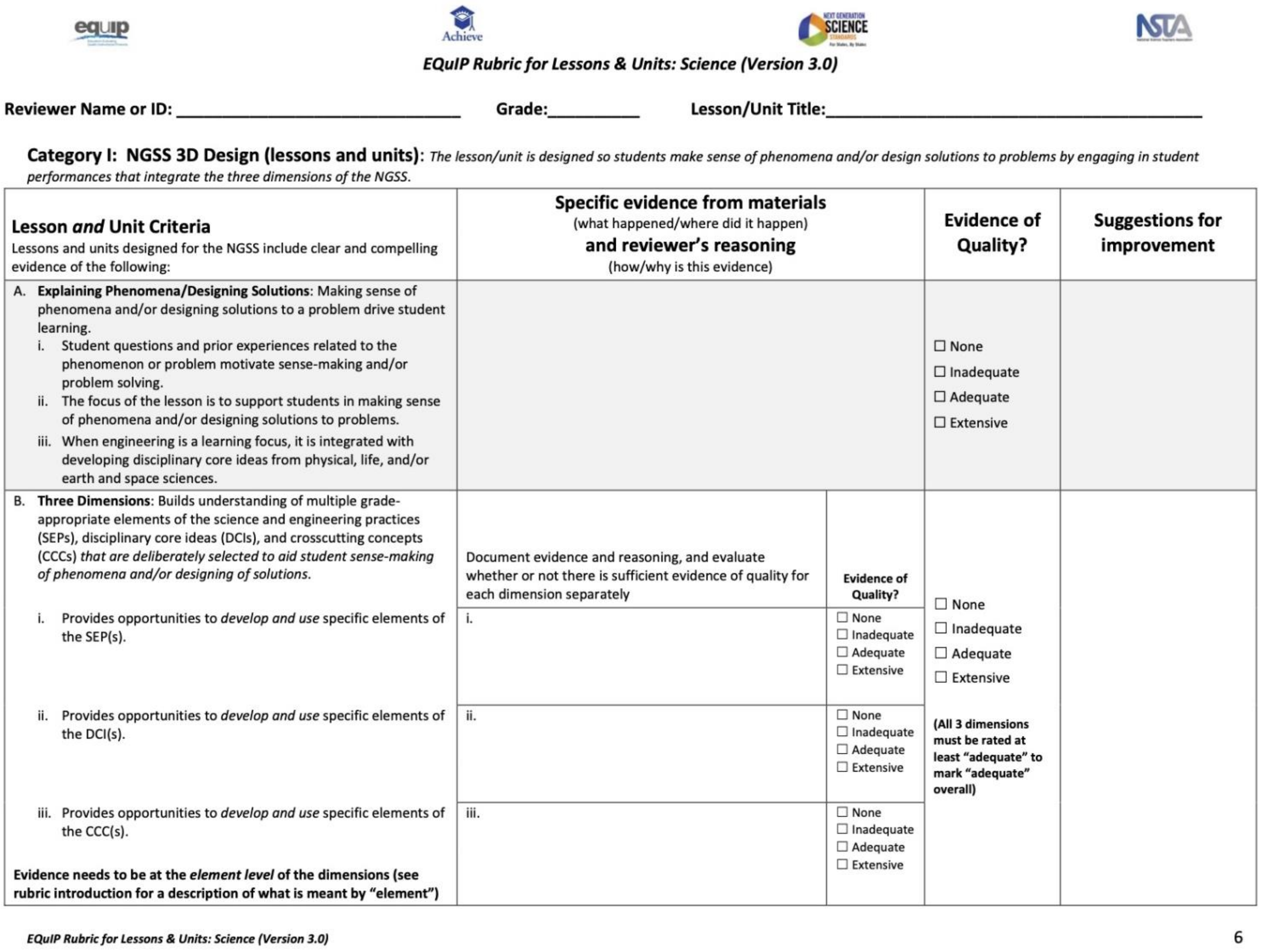
Overall Rating for the Lesson/Unit:

E: Example of high quality NGSS design—High quality design for the NGSS across all three categories of the rubric; a lesson or unit with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across Categories I, II, & III of the rubric. (total score ~8–9)

E/I: Example of high quality NGSS design if Improved—Adequate design for the NGSS, but would benefit from some improvement in one or more categories; most criteria have at least adequate evidence (total score ~6–7)

R: Revision needed—Partially designed for the NGSS, but needs significant revision in one or more categories (total ~3–5)

N: Not ready to review—Not designed for the NGSS; does not meet criteria (total 0–2)



EQuIP Rubric for Lessons & Units: Science (Version 3.0)

Reviewer Name or ID: ______________________________ **Grade:**__________ **Lesson/Unit Title:**____

Category I: NGSS 3D Design (lessons and units): *The lesson/unit is designed so students make sense of phenomena and/or design solutions to problems by engaging in student performances that integrate the three dimensions of the NGSS.*

Lesson *and* Unit Criteria Lessons and units designed for the NGSS include clear and compelling evidence of the following:	**Specific evidence from materials** (what happened/where did it happen) **and reviewer's reasoning** (how/why is this evidence)		**Evidence of Quality?**	**Suggestions for improvement**
A. **Explaining Phenomena/Designing Solutions**: Making sense of phenomena and/or designing solutions to a problem drive student learning. i. Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving. ii. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems. iii. When engineering is a learning focus, it is integrated with developing disciplinary core ideas from physical, life, and/or earth and space sciences.			☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
B. **Three Dimensions**: Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) *that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.*	Document evidence and reasoning, and evaluate whether or not there is sufficient evidence of quality for each dimension separately	**Evidence of Quality?**	☐ None ☐ Inadequate ☐ Adequate ☐ Extensive **(All 3 dimensions must be rated at least "adequate" to mark "adequate" overall)**	
i. Provides opportunities to *develop and use* specific elements of the SEP(s).	i.	☐ None ☐ Inadequate ☐ Adequate ☐ Extensive		
ii. Provides opportunities to *develop and use* specific elements of the DCI(s).	ii.	☐ None ☐ Inadequate ☐ Adequate ☐ Extensive		
iii. Provides opportunities to *develop and use* specific elements of the CCC(s). **Evidence needs to be at the *element level* of the dimensions (see rubric introduction for a description of what is meant by "element")**	iii.	☐ None ☐ Inadequate ☐ Adequate ☐ Extensive		

C. **Integrating the Three Dimensions:** Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
Rating for Category I. NGSS 3D Design—*lessons* After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which there is enough evidence to support a claim that the lesson meets these criteria. ***If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria D-F and rate Category I overall below.***	***Lesson* Rating scale for Category I (Criteria A–C only)**: **3**: Extensive evidence to meet at least two criteria (and at least adequate evidence for the third) **2**: Adequate evidence to meet all three criteria in the category **1**: Adequate evidence to meet at least one criterion in the category, but insufficient evidence for at least one other criterion **0**: Inadequate (or no) evidence to meet any of the criteria in the category		**Select Rating** **0** ○ **1** ○ **2** ○ **3** ○ After rating the lesson, read below for next steps

<u>What's next if the lesson rating is less than a 2?</u>

If the rubric is being used to approve or vet resources and the lesson or unit does not score at least a "2" in ***Category I: NGSS 3D Designed****, the review should stop and feedback should be provided to the lesson developer(s) to guide revisions. If the rubric is being used locally for revising and building lessons, professional judgment should guide whether to continue reviewing the lesson. Categories II and III may be time consuming to evaluate if Category I has not been met and the feedback may not be useful if significant revisions are needed in Category I, but evaluating these criteria in a group may support deeper and more common understanding of the criteria in these categories and more complete feedback to the lesson developer (if they are not in the room) so that Categories II and III are more likely to be met with fewer cycles of revision.*

<u>What's next if the lesson rating is a 2 or 3?</u>

If you are evaluating a lesson that shows sufficient evidence of quality to warrant a rating of either a 2 or a 3 for Category I, proceed to Category II: NGSS Instructional Supports

Category II: NGSS Instructional Supports (lessons and units): *The lesson/unit supports three-dimensional teaching and learning for ALL students by placing the lesson in a sequence of learning for all three dimensions and providing support for teachers to engage all students.*

Lesson *and* Unit Criteria Lessons and units designed for the NGSS include clear and compelling evidence of the following:	**Specific evidence from materials and reviewers' reasoning**	**Evidence of Quality?**	**Suggestions for improvement**
A. **Relevance and Authenticity**: Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world. i. Students experience phenomena or design problems as directly as possible (firsthand or through media representations). ii. Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate. iii. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
B. **Student Ideas:** Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and respond to peer and teacher feedback orally and/or in written form as appropriate.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
C. **Building Progressions**: Identifies and builds on students' prior learning in all three dimensions, including providing the following support to teachers: i. Explicitly identifying prior student learning expected for all three dimensions ii. Clearly explaining how the prior learning will be built upon.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	

D. **Scientific Accuracy**: Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
E. **Differentiated Instruction**: Provides guidance for teachers to support differentiated instruction by including: i. Appropriate reading, writing, listening, and/or speaking alternatives (e.g., translations, picture support, graphic organizers, etc.) for students who are English language learners, have special needs, or read well below the grade level. ii. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations. iii. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
Rating for Category II: Instructional Supports—lessons After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the lesson met this category. ***If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria F–G and rate Category II overall below.***	**Lesson Rating scale for Category II (Criteria A-E only):** **3**: At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion **2**: Some evidence for all criteria in the category and adequate evidence for at least four criteria, including A **1**: Adequate evidence of quality for at least two criteria in the category **0**: Adequate evidence of quality for no more than one criterion in the category		**Select Rating** **0 1 2 3** ○ ○ ○ ○

Category III: Monitoring NGSS Student Progress (lessons and units) *The lesson/unit supports monitoring student progress in all three dimensions of the NGSS as students make sense of phenomena and/or design solutions to problems.*

Lesson and Unit Criteria Lessons and units designed for the NGSS include clear and compelling evidence of the following:	**Specific evidence from materials and reviewers' reasoning**	**Evidence of Quality?**	**Suggestions for improvement**
A. **Monitoring 3D student performances**: Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
B. **Formative:** Embeds formative assessment processes throughout that evaluate student learning to inform instruction.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
C. **Scoring guidance**: Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
D. **Unbiased tasks/items**: Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.		☐ None ☐ Inadequate ☐ Adequate ☐ Extensive	
Rating for Category III. Monitoring NGSS Student Progress—*lessons* After carefully weighing the evidence, reasoning, and suggestions for improvement, rate the degree to which the lesson met this category. ***If you are evaluating an instructional unit rather than a single lesson, continue on to evaluate criteria E–F and rate Category III overall below.***	***Lesson* Rating scale for Category III (Criteria A–D only):** **3**: At least adequate evidence for all criteria in the category; extensive evidence for at least one criterion **2**: Some evidence for all criteria in the category and adequate evidence for at least three criteria, including A **1**: Adequate evidence for at least two criteria in the category **0**: Adequate evidence for no more than one criterion in the category		**Select Rating** **0** ○ **1** ○ **2** ○ **3** ○

Category Ratings:

Transfer your team's ratings from each category to the following chart and add the scores together for the overall score:

Category ratings			**Total Score**
Category I: **NGSS 3D Design**	**Category II:** **NGSS Instructional Supports**	**Category III:** **Monitoring NGSS Student Progress**	
0 ○ 1 ○ 2 ○ 3 ○	0 ○ 1 ○ 2 ○ 3 ○	0 ○ 1 ○ 2 ○ 3 ○	

Overall ratings: The score total is an *approximate* guide for the rating. Reviewers should use the evidence of quality across categories to guide the final rating. In other words, the rating could differ from the total score recommendations if the reviewer has evidence to support this variation.	**E: Example of high quality NGSS design**—High quality design for the NGSS across all three categories of the rubric; a lesson or unit with this rating will still need adjustments for a specific classroom, but the support is there to make this possible; exemplifies most criteria across Categories I, II, & III of the rubric. (total score ~8–9) **E/I: Example of high quality NGSS design if Improved**—Adequate design for the NGSS, but would benefit from some improvement in one or more categories; most criteria have at least adequate evidence (total score ~6–7) **R: Revision needed**—Partially designed for the NGSS, but needs significant revision in one or more categories (total ~3–5) **N: Not ready to review**—Not designed for the NGSS; does not meet criteria (total 0–2)	**Select the overall rating below:** **E** ○ **E/I** ○ **R** ○ **N** ○

Overall Summary Comments:

Appendix C - Electronic Quality of Inquiry Protocol

Complete Sections I before and during observation, Sections II and III during the observation, and Sections IV-VII immediately after the observation. If a construct in Sections IV-VI absolutely cannot be coded based on the observation, then it is to be left blank.

Observation date: ________ Time start:______ Time end: _____ Observer: ____________________________

School:________________________District:__________________________Teacher:_____________________________

Course: _____________________

I. *Descriptive Information*

A. Teacher Descriptive Information:

1. Teacher gender ____Male (M), Female (F)
2. Teacher ethnicity______(American Indian or Alaska Native, Asian, Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, or White)
3. Grade level(s) observed__4. Subject/Course observed __

5. Highest degree_________________6. Number of years experience:_________7. Number of years teaching this content ____

B. Student/Class Descriptive Information

1. Number of students in class: __________
2. Gender distribution:____Males_____Females
3. Ethnicity distribution_____Caucasian (C)_____African-American (A)_____Latino (L)______ White (W)____________Other

C. Lesson Descriptive Information

1. Is the lesson an exemplar that follows the 4E x 2 Instructional Model? (PDI exemplar, non-PDI exemplar, non-exemplar)
2. Working title for lesson:
3. Objectives/Purpose of lesson: Inferred (I), Explicit (E)__:
4. Standards addressed: State (S), District (D), None Explicit (N)__:

II. Time Usage Analysis						
Time	**Activity Codes**	**Organization Codes**	**Student Attention to Lesson Codes**	**Cognitive Codes**	**Inquiry Instruction Component Codes**	**Assessment Codes**
0-5						
5-10						
10-15						
15-20						
20-25						
25-30						
30-35						
35-40						
40-45						
45-50						
50-55						
55-60						
60-65						
65-70						
70-75						
75-80						
80-85						
85-90						

Activity Codes—facilitated by teacher

0. **Non-instructional time**—administrative tasks, handing back/collecting papers, general announcements, time away from instruction
1. **Pre-inquiry**—teacher-centered, passive students, prescriptive, didactic discourse pattern, no inquiry attempted
2. **Developing inquiry**—teacher-centered with some active engagement of students, prescriptive though not entirely, mostly didactic with some open-ended discussions, teacher dominates the explain, teacher seen as both giver of knowledge and as a facilitator, beginning of class warm-ups
3. **Proficient inquiry**—largely student-centered, focus on students as active learners, inquiries are guided and include student input, discourse includes discussions that emphasize process as much as product, teacher facilitates learning and students active in all stages, including the explain phase
4. **Exemplary inquiry**—student-centered, students active in constructing understanding of content, rich teacher-student and student-student dialogue, teacher facilitates learning in effective ways to encourage student learning and conceptual development, assumptions and misconceptions are challenged by students and teacher

Organization Codes—led by teacher

W Whole class
S Small group
X Individual work

Student Attention to Lesson Code—displayed by students

L **Low attention**, 20% or fewer attending to the lesson. Most students are off-task – heads on desks, staring out of the window, chatting with neighbors, etc.
M **Medium attention**, between 20-80% of students are attending to the lesson.
H **High attention**, 80% or more of the students are attending to the lesson. Most students are taking notes or looking at the teacher during lecture, writing on the worksheet, most students are volunteering ideas during a discussion, most students are engaged in small group discussions even without the presence of the teacher.

Cognitive Code—displayed by students

0. Other-e.g. classroom disruption, non-instructional portion of lesson, administrative activity
1. Receipt of knowledge
2. Lower order (recall, remember, understand) and/or activities focused on completion exercises, computation
3. Apply (demonstrate, modify, compare) and/or activities focused on problem solving
4. Analyze/Evaluate (evidence, verify, analyze, justify, interpret)
5. Create (combine, construct, develop, formulate)

Inquiry Instructional Component Code—facilitated by teacher

0. **Non-inquiry**: activities with the purpose of skill automation; rote memorization of facts; drill and practice; checking answers on homework, quizzes, or classwork with little or no explanation
1. **Engage**: typically situated at the beginning of the lesson; assessing student prior knowledge and misconceptions; stimulating student interest
2. **Explore**: students investigate a new idea or concept
3. **Explain**: teacher or students making sense of an idea or concept

Extend: [Extend is important but is not coded as such because it typically is a new Engage, Explore, or Explain]

Assessment Code—facilitated by teacher

0. **No assessment observed**
1. **Monitoring** (circulating around the room, probing for understanding, checking student progress, commenting as appropriate)
2. **Formative assessment** (assessing student progress, instruction modified to align with student ability) or **Diagnostic assessment** (checking for prior knowledge, misconceptions, abilities)
3. **Summative assessment** (assessing student learning, evaluative and not informing next instructional step)

III. Lesson Descriptive Details		
Time (mins into class)	Classroom Notes of Observation	Comments

Time (mins into class)	Classroom Notes of Observation	Comments

Time (mins into class)	Classroom Notes of Observation	Comments

Time (mins into class)	Classroom Notes of Observation	Comments

Time (mins into class)	Classroom Notes of Observation	Comments

IV. Instructional Factors

Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
I1.	Instructional Strategies	Teacher predominantly lectured to cover science content.	Teacher **frequently lectured** and/or used demonstrations to explain content. Engineering design activities were **verification only**.	Teacher **occasionally lectured**, but **students were engaged in** Engineering design activities that helped develop science conceptual understanding.	Teacher occasionally lectured, but students were engaged in investigations that **promoted strong science conceptual understanding**.
I2.	Order of Instruction	Teacher explained science concepts. Students either did not explore concepts or did so only after explanation.	Teacher asked **students to explore science concepts before receiving explanation**. Teacher explained.	Teacher asked students to **explore science concept before explanation**. **Teacher and students explained**.	Teacher promotes students to explore **science** concept during the EDI. **students provided the explanation**.
I3.	Teacher Role	Teacher was center of lesson; rarely acted as facilitator.	**Teacher was center** of lesson; **occasionally** acted as f**acilitator**.	Teacher **frequently** acted as facilitator.	Teacher **consistently and effectively** acted as a facilitator.
I4.	Student Role	Students were consistently passive as learners (taking notes, practicing on their own).	**Students were active to a small extent** as learners (highly engaged for very brief moments or to a small extent throughout lesson).	**Students were active as learners** (involved in SEPs, but not consistently and clearly focused).	Students were **consistently and effectively active as learners** (highly engaged in SEPs during lesson and clearly focused on the task).
I5.	Knowledge Acquisition	Student learning focused solely on mastery of science content, information, and/or rote processes.	Student learning focused on **mastery of** DCIs and SEPs without much focus on understanding of content.	Student learning required **application of** DCIs and SEPs in new situations.	Student learning required **depth of understanding** to be demonstrated relating to DCI, SEPs, and CCCs

Note. The highlighted words indicate the phrases modified by the researcher

V. ***Discourse Factors***					
Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
D1.	Questioning Level	Questioning rarely challenged students above the remembering level.	Questioning rarely challenged students above the **understanding level**.	Questioning challenged students **up to application or analysis levels**.	Questioning challenged students at various levels, **including at the analysis level or higher; level was varied to scaffold learning.**
D2.	Complexity of Questions	Questions focused on one correct answer; typically short answer responses.	Questions focused **mostly on one correct answer;** some open response opportunities.	Questions **challenged students to explain, reason, and/or justify**.	Questions required students to explain, reason, and/or justify. **Students were expected to critique others' responses**.
D3.	Questioning Ecology	Teacher lectured or engaged students in oral questioning that did not lead to discussion.	Teacher occasionally **attempted to engage students in discussions** or investigations but was not successful.	Teacher **successfully engaged students** in open-ended questions, discussions, and/or investigations.	Teacher **consistently and effectively engaged students** in open-ended questions, discussions, investigations, and/or reflections.
D4.	Communication Pattern	Communication was controlled and directed by teacher and followed a didactic pattern.	Communication was **typically controlled and directed by teacher** with occasional input from other students; mostly didactic pattern.	**Communication was often conversational** with some student questions guiding the discussion.	Communication was **consistently conversational with student questions often guiding the discussion**.
D5.	Classroom Interactions	Teacher accepted answers, correcting when necessary, but rarely followed-up with further probing.	Teacher or another student **occasionally followed-up student response** with further low-level probe.	Teacher or another student **often followed-up response** with engaging probe that required student to **justify reasoning or evidence**.	Teacher **consistently and effectively facilitated rich classroom dialogue** where evidence, assumptions, and science reasoning were challenged by teacher or other students.

<table>
<tr><th colspan="6">VI. Assessment Factors</th></tr>
<tr><th colspan="2">Construct Measured</th><th>Pre-Inquiry (Level 1)</th><th>Developing Inquiry (2)</th><th>Proficient Inquiry (3)</th><th>Exemplary Inquiry (4)</th></tr>
<tr><td>A1.</td><td>Prior Knowledge</td><td>Teacher did not assess student prior knowledge.</td><td>Teacher assessed student prior knowledge but did not modify instruction based on this knowledge.</td><td>Teacher assessed student prior knowledge and then partially modified instruction based on this knowledge.</td><td>Teacher assessed student prior knowledge and then modified instruction based on this knowledge.</td></tr>
<tr><td>A2.</td><td>Conceptual Development</td><td>Teacher encouraged learning by memorization and repetition.</td><td>Teacher encouraged product- or answer-focused learning activities that lacked critical thinking.</td><td>Teacher encouraged process-focused learning activities that required critical thinking.</td><td>Teacher encouraged process-focused learning activities that involved critical thinking that connected learning with other concepts.</td></tr>
<tr><td>A3.</td><td>Student Reflection</td><td>Teacher did not explicitly encourage students to reflect on their own learning.</td><td>Teacher explicitly encouraged students to reflect on their learning but only at a minimal knowledge level.</td><td>Teacher explicitly encouraged students to reflect on their learning at an understanding level.</td><td>Teacher consistently encouraged students to reflect on their learning at multiple times throughout the lesson; encouraged students to think at higher levels.</td></tr>
<tr><td>A4.</td><td>Assessment Type</td><td>Formal and informal assessments measured only factual, discrete knowledge.</td><td>Formal and informal assessments measured mostly factual, discrete knowledge.</td><td>Formal and informal assessments used both factual, discrete knowledge and authentic measures.</td><td>Formal and informal assessment methods consistently and effectively used authentic measures.</td></tr>
<tr><td>A5.</td><td>Role of Assessing</td><td>Teacher solicited predetermined answers from students requiring little explanation or justification.</td><td>Teacher solicited information from students to assess understanding.</td><td>Teacher solicited explanations from students to assess understanding and then adjusted instruction accordingly.</td><td>Teacher frequently and effectively assessed student understanding and adjusted instruction accordingly; challenged evidence and claims made; encouraged curiosity and openness.</td></tr>
</table>

VII. Curriculum Factors					
Construct Measured		*Pre-Inquiry (Level 1)*	*Developing Inquiry (2)*	*Proficient Inquiry (3)*	*Exemplary Inquiry (4)*
C1.	Content Depth	Lesson provided only superficial coverage of science content.	Lesson provided **some depth** of content but with **no connections made to the engineering design activity**	Lesson provided depth of content with **some significant connection** to the **engineering design activity**	Lesson provided depth of content with **significant, clear, and explicit connections** made to **engineering design activity**
C2.	Learner Centrality	Lesson did not engage learner in Engineering design activities or investigations.	Lesson provided **prescribed engineering design activities** with anticipated results.	Lesson allowed for **some flexibility during investigation** for student-designed exploration.	Lesson provided **flexibility for students to design and carry out** their own investigations.
C3.	Integration of Content and Investigation	Lesson either science content-focused or engineering design activities-focused but not both.	Lesson provided poor integration of science content in engineering design activities	Lesson **incorporated student** engineering design activities **that linked well with science content**.	Lesson **seamlessly integrated the content and the student** engineering design activities .
C4.	Organizing & Recording Information	Students organized and recorded information in prescriptive ways.	**Students had only minor input as to how to organize and record information**.	Students regularly organized and recorded information in **non-prescriptive ways**.	Students organized and recorded information in **non-prescriptive** ways (EDP) that allowed them to **effectively communicate their science learning.**

Note. The highlighted words indicate the phrases modified by the researcher

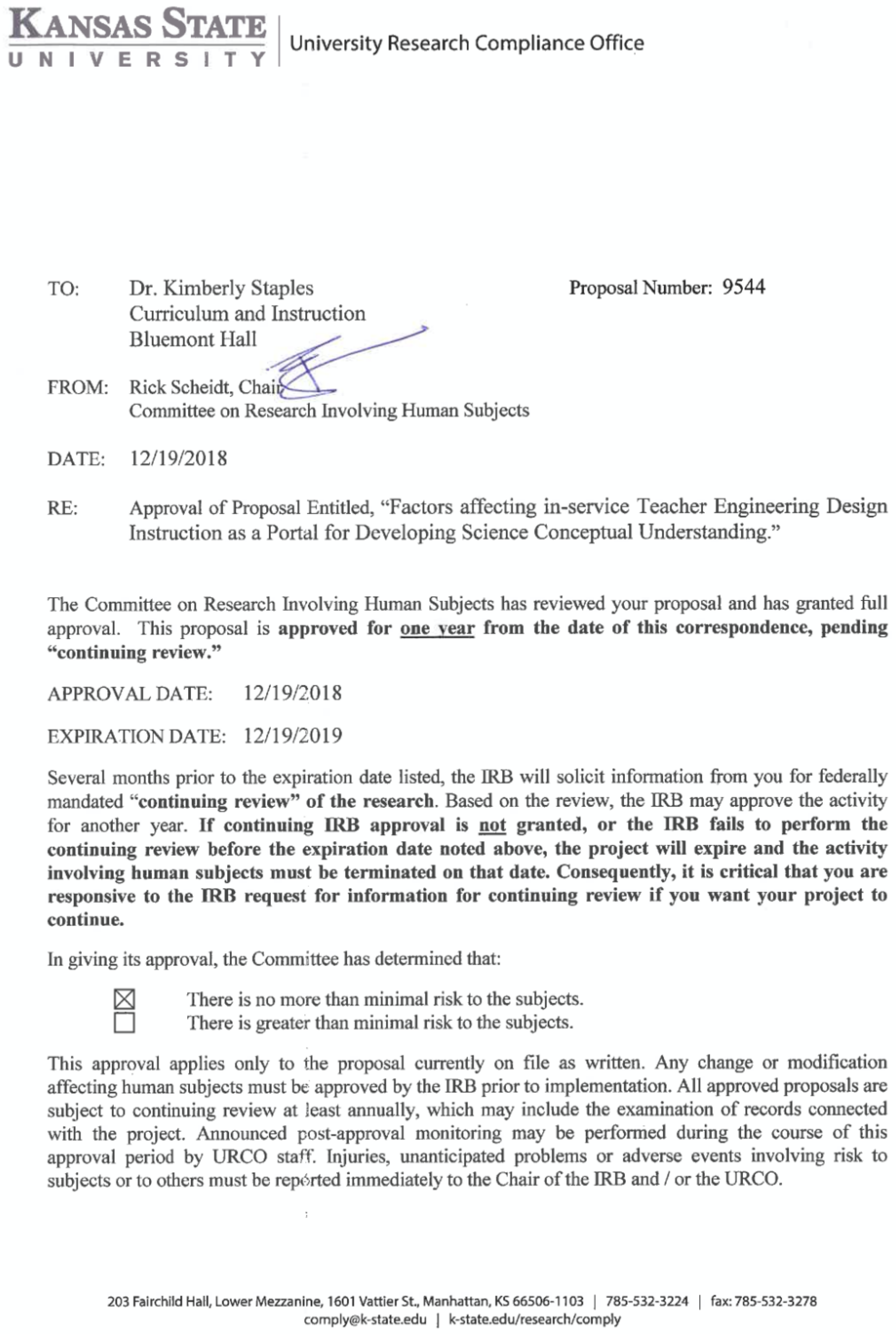
VIII. Summative Overviews*		*Comprehensive Score***
Summative view of Instruction		
Summative view of Discourse		
Summative view of Assessment		
Summative view of Curriculum		
Overall view of Lesson		

*Provide brief descriptive comments to justify score.

**Score for each component should be an integer from 1-4 that corresponds with the appropriate level of inquiry. Scores should reflect the essence of the lesson relative to that component, so they need not be an exact average of all sub-scores in a category.

Marshall, J. C., Horton, B., Smart, J., & Llewellyn, D. (2008). *EQUIP: Electronic Quality of Inquiry Protocol*: Retrieved from Clemson University's Inquiry in Motion Institute, www.clemson.edu/iim.

Appendix D - The IRB Approval



KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Dr. Kimberly Staples
Curriculum and Instruction
Bluemont Hall

Proposal Number: 9544

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 12/19/2018

RE: Approval of Proposal Entitled, "Factors affecting in-service Teacher Engineering Design Instruction as a Portal for Developing Science Conceptual Understanding."

The Committee on Research Involving Human Subjects has reviewed your proposal and has granted full approval. This proposal is **approved for <u>one year</u> from the date of this correspondence, pending "continuing review."**

APPROVAL DATE: 12/19/2018

EXPIRATION DATE: 12/19/2019

Several months prior to the expiration date listed, the IRB will solicit information from you for federally mandated "**continuing review" of the research**. Based on the review, the IRB may approve the activity for another year. **If continuing IRB approval is <u>not</u> granted, or the IRB fails to perform the continuing review before the expiration date noted above, the project will expire and the activity involving human subjects must be terminated on that date. Consequently, it is critical that you are responsive to the IRB request for information for continuing review if you want your project to continue.**

In giving its approval, the Committee has determined that:

☒ There is no more than minimal risk to the subjects.
☐ There is greater than minimal risk to the subjects.

This approval applies only to the proposal currently on file as written. Any change or modification affecting human subjects must be approved by the IRB prior to implementation. All approved proposals are subject to continuing review at least annually, which may include the examination of records connected with the project. Announced post-approval monitoring may be performed during the course of this approval period by URCO staff. Injuries, unanticipated problems or adverse events involving risk to subjects or to others must be reported immediately to the Chair of the IRB and / or the URCO.

203 Fairchild Hall, Lower Mezzanine, 1601 Vattier St., Manhattan, KS 66506-1103 | 785-532-3224 | fax: 785-532-3278
comply@k-state.edu | k-state.edu/research/comply