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An Investigation of the Effects of Self-Efficacy on STEM Implementation

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Abstract

In order to equip students with the 21st Century skills necessary for today's society, STEM education must be properly implemented in school curricula (Lamb, Akmal, & Petrie, 2015). To do so, it is important for teachers to possess both proficient knowledge of the subject matter and confidence towards the implementation of STEM. A person's beliefs about their ability is known as their self-efficacy (Bandura 1997). Related to education, Bandura notes that this self-efficacy affects a teacher's views on their ability to handle tasks, obligations, and challenges related to a challenge (1997). Additionally, numerous studies indicate that this self-efficacy in turn affects actual performance in the classroom (Katzenmeyer & Lawrenz, 2006; Smith, Douglas, & Cox, 2009). With this in mind, this study was designed to survey teachers in the Northwest Arkansas area (Washington and Benton counties) and determine the extent to which STEM education and project-based learning is being implemented. In order to gain insight into the research questions, the researcher distributed the STEM Efficacy Survey Instrument to a random pool of elementary educators over a two week period in February 2021. This instrument surveyed elementary teachers on their previous background in STEM, their feelings towards their ability to implement STEM, and their actual implementation of STEM. From this research, the researcher concluded that higher training in STEM resulted in higher confidence in teachers ability which in turn resulted in higher rates of implementation. More research on the affects of self-efficacy on STEM implementation needs to be conducted in order to gain a more complete picture of what measures should be taken in order to increase teacher self-efficacy, and in turn increasing implementation.

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Introduction

STEM education is instruction combining Science, Technology, Engineering, and Mathematics subject matter, and it is growing in prevalence in elementary schools. This instruction encompasses more than just these four disciplines as it's hands-on nature allows students to develop a variety of 21st century skills. In order to equip students with the 21st Century skills necessary for today's society, STEM education must be properly implemented in school curricula (Lamb, Akmal, & Petrie, 2015). To do so, it is critical for teachers to possess proficient knowledge of the subject matter and effective methods to incorporate the project-based teaching pedagogy. However, due to the generalist nature of elementary teacher preparation, many elementary teachers' possess limited knowledge of STEM and the supporting STEM pedagogies, which can result in low teacher self-efficacy related to STEM (Rittmayer & Beier, 2008). Self-efficacy is a person's confidence in their ability to complete tasks to their highest potential (Bandura, 1997). Countless studies have demonstrated a connection between teacher self-efficacy and student success (Katzenmeyer & Lawrenz, 2006; Smith, Douglas, & Cox, 2009). Therefore, it is important to determine the level of self-efficacy teachers have towards STEM instruction so that proper interventions can be made.

Importance of STEM Education

STEM-based learning focuses on providing students with hands-on, problem-based learning objectives that develop a variety of skills. Through the utilization of the Engineering Design Process, students are encouraged to integrate subjects and to come up with creative solutions to problems and challenges (Havice, 2015). This learning method fosters the 4 C's of 21st century skills which are critical thinking, collaboration, creativity, and communication (Claymier, 2014). STEM-based learning goes beyond the four subjects that comprise it. In fact, it provides students with opportunities in the classroom to gain real-life skills such as leadership, acceptance of failure, problem solving, productivity, innovation, and flexibility. Additionally, STEM education is often structured as Project Based Learning (PBL) (Havice, 2015). This type of learning has been proven to be more engaging for students and can lead to better retention of knowledge.

As society continues to advance, the need for STEM-related jobs continues to grow. The Smithsonian Science Education Center reported that these jobs grew at a rate three times faster than non-STEM jobs between 2000 and 2010 (Smithsonian, 2016). Furthermore, the National Academies of Sciences, Engineering, and Medicine estimates that there will be 3.4 million unfilled skilled technical jobs by 2022 (2017). Along with these unfilled jobs, there is an extreme gender gap in the STEM field. Women make up only 28% of the workforce and many girls lose confidence in math by third grade (Lubienski et al., 2013). STEM-based education can work to spark interest in girls and give them the confidence to close the gender gap. These programs are important to prepare today's children to become the innovators of tomorrow.

Why it is Not Being Taught Enough

Though research has shown that STEM programs in the classroom are beneficial, there are still not enough schools integrating STEM into the curriculum. There are multiple factors contributing to this deficiency. First, STEM is a relatively new grouping for elementary schools. Schools currently struggle, as it is, to meet performance standards which may lead them to overlook STEM programs (Johnson, 2020; An & Cardona-Maguigad, 2019). Additionally, teachers are not always comfortable and confident in the implementation skills that are required of STEM instruction (Katzenmeyer & Lawrenz, 2006; Smith, Douglas, & Cox, 2009). As these programs are relatively new, a lot of experienced teachers may not have had formal STEM training, nor did they focus on STEM while engaged in teacher preparation programs at the university (Brusic, & Shearer, 2014) . Similarly, the role of the teacher in project-based learning is different as the teacher shifts to a role as a facilitator. Studies have shown that this transition is often difficult for teachers (Daugherty & Carter, 2017). The combination of these challenges, along with other factors, may indicate why STEM education is underutilized in elementary schools in America.

Importance of Teacher Self-Efficacy

When considering reasons why STEM is not being taught widely in school, research points to teachers' concerns about their ability to implement it. Bandura noted that teacher self-efficacy is a teacher's belief in their ability to effectively handle the tasks, obligations, and challenges related to an activity (1997). Extensive research has supported claims that self-efficacy influences the teacher's achievement, and in turn influences the students' achievement (Katzenmeyer & Lawrenz, 2006; Smith, Douglas, & Cox, 2009). Additionally, STEM may influence student behaviors and may motivate students in the elementary classroom (Klassen, 2010). These, and other studies illustrate that it is important for teachers to feel assured in their abilities to implement STEM education in the classroom. Through exposure and training, teachers may better be able to increase their efficacy, in turn resulting in more prevalent integration of STEM education in the classroom.

Purpose and Significance of This Study

With these things in mind, this study was designed to determine the extent to which STEM education and project-based learning is being implemented in the elementary classroom. Specifically, this research was designed to measure elementary teachers attitudes towards STEM instruction. Additionally, this research was designed to assess elementary teacher experience in

STEM education and the how they have previously implemented STEM educational experiences in the classroom. This included isolating factors such as methodology and frequency. Through this survey research, the author sought to determine whether there was a connection between training, self-efficacy and implementation of STEM education in the elementary classroom. If these connections can be made, a relationship between teacher self-efficacy and student success can also be made, as extensive research supports the positive correlation between these two (Skaalvik & Skaalvik, 2007; Tschannen-Moran & Woolfolk Hoy, 2001; Catalano, 2019; Mujis & Rejnolds, 2001; Tournaki & Podell, 2005).

Literature Review

The researcher conducted a review of relevant literature in order to explore the key components of STEM education. To do so, the researcher looked at the content of STEM curriculum, its implementation, the effects of teacher self-efficacy generally, and the implications of self-efficacy specifically on STEM curriculum.

With the seemingly unstoppable expansion of technology into all facets of society, the job market has experienced an unprecedented demand for individuals with training and degrees in STEM related fields (Havice, 2015). As noted by Dejarnette, students who are exposed to STEM programs during elementary and secondary school have a higher likelihood of continuing on to pursue degrees and careers with a focus on STEM (2012). This would indicate that increasing STEM interventions at younger ages could increase the number of individuals willing and able to fill the growing needs of the job market. Additionally, schools began integrating STEM curriculum as it became apparent that the instruction can aid students in making connections from one content area to another (Berry et al. 2004). For both of these reasons, reform initiatives began to experiment with the integration of engineering and technology into math and science classrooms (Margot &

Kettler, 2019). However, in order to effectively incorporate STEM in a way that reaps these benefits, researchers soon discovered that teacher understanding and confidence are critical components of such STEM integration (Widya, 2019). Yet many elementary educators continue to be prepared as generalists and sometimes lack the in-depth preparation for STEM teaching that would enable them to feel confident in their ability to develop or deliver the curriculum. For this reason, the researcher conducted this review based on previously conducted research to investigate the curriculum of STEM, the integration of the curriculum into schools, and ways in which self-efficacy can impact the implementation.

STEM Curriculum

STEM curriculum refers to a discipline that focuses on the content areas of science, technology, engineering, and mathematics. For the past several decades, STEM professionals have struggled to provide elementary school teachers with the ideas and resources necessary to enact STEM activities in public schools (Brusic & Shearer, 2014). However, with the rise of technology in society and the growing STEM job market, it is critical for schools to find programs that allow for STEM to be integrated into their curriculum.

Integrated STEM refers to curriculum that combines the four content areas while taking an engineering design-based learning approach. STEM education can serve as a tool to develop students' 21st century skills. This involves heightening skills such as problem solving, critical thinking, communication, collaboration, and creativity (Claymier, 2014; Brusic, 2014). The hands-on nature of integrated STEM naturally involves the development of these skills, and this curriculum can provide students with connections between school and the world around them.

Interdisciplinary STEM is the approach by which students learn the interconnectedness of the four content areas of STEM (Daugherty & Carter, 2017). These programs can inspire heightened levels 21^{st} century skills while also providing a deeper understanding of the content knowledge. This interdisciplinary curriculum allows for the four content areas to be integrated along with content areas such as language arts, social studies, and art (Havice, 2015). This approach to STEM is inquiry-based and introduces problem-based learning and engineering design as a means to create solutions through the application of content knowledge. Accordingly, this approach allows for real-world connections and preparation for STEM pathways and careers (Margot & Kettler, 2019).

According to research conducted by Daugherty and Carter, some consider the engineering design process (EDP) to be the cornerstone of STEM education (2017). This process involves clearly defining a problem, generating potential ideas, selecting a plan, building the plan, testing it, and then communicating the results (Cunningham, Mott, & Hunt, 2018). The EDP fosters creativity, innovation, and inventiveness as it guides the application of creative solutions to problems. This application requires students to use cognitive and procedural knowledge to create and carry out a design that will solve a particular problem. This demands critical thinking, consideration of STEM concepts, creativity, and application of technical knowledge (Daugherty & Carter, 2017). Additionally, the EDP provides students with practical tools and practice with deductive reasoning and arriving at solutions to ill-structured problems.

When providing students with the opportunity to use the EDP, problem-based learning (PBL) is an essential approach. According to Savery there are specific characteristics in a problem-based learning classroom (2006). Firstly, the learning is comprised of ill-structured learning challenges where more than one outcome is likely. Additionally, the teacher assumes the role of facilitator while the students self-direct and self-regulate their learning. This requires students to engage in cooperative learning as they collaborate to solve problems through questioning techniques, research, and experimentation. This type of learning can help invigorate a student's desire to engage in the classroom and make sense of the world that surrounds them (Daugherty & Carter, 2017).

The chief concern of STEM education is the link between educators' content knowledge and their ability to integrate STEM learning into the classroom (Daugherty & Carter, 2017). According to Stohlmann et al., the four major components of an integrated STEM approach are: opportunities for collaboration and professional development, instruction that is focused on integrated lesson planning, efficacy and commitment to STEM education, and access to necessary materials and resources (2012). As STEM integration is relatively new, especially at the elementary level, it is vital to understand these components in order to successfully implement a STEM initiative in the classroom.

Successful Implementation of STEM in the Classroom

When implementing STEM programs in the classroom, the central importance of implementation is the integration of scientific and engineering practices while emphasizing core concepts and student engagement (Capobianco & Rupp, 2014). Rogan and Grayson suggest that there are three major components that ensure implementation. They include: profile of implementation, capability to innovate, and outside support (2003). The profile of implementation refers to the classroom environment. This profile is comprised of the types of student-teacher interactions, the use of science and practical work, and assessment practices. The capability to innovate refers to the physical resources such as materials, space, and equipment as well as student and teacher factors such as knowledge, confidence, commitment, and previous experiences.

Finally, outside support refers to the actions taken by organizations outside of the school to influence the implementation. This may include things such as the state department of education or outside funding (Capobianco & Rupp, 2014). These factors all play a critical role and impact the implementation of a STEM program and should be considered when developing an integrated STEM curriculum.

In order to maximize the effects of STEM, early interventions are vital and should also be considered when implementing integrated STEM learning. The effects of early intervention serve as evidence as to why it is important for elementary educators to become well-versed in the pedagogy. Studies have shown that by third grade, many girls lose confidence in their ability for math and science content knowledge (Lubienski et al., 2013). Furthermore, other studies show in general by the age of 10-14 students have formed their confidence and attitude towards STEM subject areas (Daugherty & Carter, 2017). Regrettably, many STEM programs are not introduced until secondary school or high school, past the point where students have formed their opinions toward these subject areas. For example, 20 percent of students have lost interest in science by 4^{th} grade. This number jumps to almost 50 percent of students losing interest or deeming the content irrelevant by 8^{th} grade (Daugherty & Carter, 2017). This may provide evidence as to why it is so important to have early interventions and integration of STEM programs in order to provide students with relevancy and meaningful experiences early. The challenge with this may impugn the very nature of traditional elementary education training. Looking at the degree programs of traditional elementary teacher education, the curriculum is generic with the goal of covering all subject matters in a fairly shallow fashion (Brusic & Shearer, 2014). This often results in educators feeling apprehensive about their ability to implement an integrated STEM program or other programs that include deeper levels of math, engineering or science (Daugherty & Carter, 2017;

Catalano, 2019; Rittmayer & Beier, 2009). Supporting these assertions, several researchers have noted that elementary educators may need interventions to help increase self-efficacy towards implementing these programs which may in turn increase student self-efficacy in STEM classes. Additionally, due to the hands-on nature of STEM, students' self-efficacy will increase their skill sets that extend beyond the walls of the STEM classroom (Havice, 2015; Margot & Kettler, 2019).

Teacher Self-Efficacy

As Bandura suggested, self-efficacy refers to the beliefs an individual holds about their ability to complete a task successfully (1997). These beliefs effect teachers in the classroom, as teachers with a strong sense of self-efficacy can motivate their students and improve their cognitive development (Bandura, 1994). Studies have also shown that self-efficacy has been associated with teacher effort and persistence, professional commitment, openness to new methods, and the use of positive strategies to deal with student problems (Mojavezi, 2012). Supporting these assertions, Ashton and Webb note that highly efficacious teachers tend to exhibit better organization, have more developed questioning and instructional skills, and provide better feedback to students (1986). These implications serve as evidence as to why it is important for teachers to have a high sense of self-efficacy in the subject areas that they teach—It directly affects their students.

According to Rittmayer and Beier, an individual's self-efficacy is based on four primary sources of information: mastery experiences, vicarious experiences, social persuasion, and physiological reactions (2008). Mastery experiences refer to prior personal task experiences and performance. Additionally, successful outcomes typically increase self-efficacy while failures lower it. Vicarious experiences refer to learning through the observation of others performing a task. Social persuasion is the effects that judgments, feedback, and support from others has on self-efficacy. This is particularly powerful when the source of social persuasion comes from influential figures and is accompanied by a mastery experience. For example, positive feedback from a teacher or parent boosts self-efficacy especially when it is aligned to past performance and actual ability. Finally, physiological reactions refers to the emotional and physical states, like butterflies in the stomach, that determine self-efficacy beliefs. Knowing the four factors that can influence self-efficacy is important when trying to increase teacher self-efficacy in STEM fields and when preparing elementary teachers to deliver integrated STEM in the primary grades.

The Implications of Teacher Self-Efficacy

As studies have shown that self-efficacy is a significant predictor for motivation and ultimately task performance, it is important to understand the implications that teacher self-efficacy has on the implementation of an integrated STEM program. Individuals with high STEM self-efficacy perform better and persist longer in the field than those with low STEM self-efficacy (Rittmayer & Beier, 2008). However, as previously stated, elementary teachers commonly hold lower self-efficacy views towards mathematics and science (Catalano, 2019). Therefore, steps like increasing preparation and training should be taken in order to increase those efficacious views.

Higher self-efficacy is positively related to teacher well-being. Studies have shown that teachers with high levels of self-efficacy tend to use more effective teaching strategies, are more dedicated to the profession, and are less likely to burn out or leave teaching (Catalano, 2019). Since more than 41 percent of teachers leave the profession within five years of starting and about half a million U.S. teachers leave the profession each year, the link between self-efficacy and job satisfaction is important to know (Seidel, 2014; Ingersoll, Merrill, & Stuckey, 2014). It is important to study the links between job satisfaction and self-efficacy in order to take the necessary steps to increase teacher retention and effectiveness in the classroom.

While the effects self-efficacy has on the well-being of the teacher are important, it is equally important to note that a teacher's level of self-efficacy also affects students' achievement and motivation (Klassen, 2010; Catalano, 2019; Mojavezi, 2012). The nature of STEM learning differs from traditional science and math instruction. Studies have shown that when it comes to science and math instruction, teachers often heavily rely on textbooks, traditional approaches that are not student-centered, and the overuse of outside experts (Goodnough et al. 2014). An integrated STEM approach requires teachers to take a different role and provide students with enriching hands-on experiences. Due to the generalist nature of elementary educator training, teachers' self-efficacy may be low in STEM areas which leads to avoidance when it comes to the implementation of STEM initiatives. This can result in lowered self-efficacy which leads to negative results from the students under the direction of teachers with lower self-efficacy. However, numerous studies have illustrated that teachers with high self-efficacy are more likely to implement classroom management approaches and teaching methods that encourage students' autonomy (Mojavezi, 2012). Developing student independence is vital to PBL and integrated STEM as the teacher takes the role of facilitator and the students are more self-directed and self-regulated.

Tournaki and Podell (2005) suggest that highly efficacious teachers make fewer negative predictions about students and are more likely to adjust their predictions if student characteristics change. Considering that social persuasion, especially from influential figures, is one of the four primary influencers of self-efficacy, it is essential for teachers to hold these positive predictions about students. As stated in Gardner's motivation theory, students are more motivated to learn and achieve when they believe that their teachers care about them and their success (1985). Therefore, highly efficacious teachers make more positive predictions which in turn positively affect their students. Additionally, studies have shown that the decline of girl's confidence in STEM does not always have to do with their actual ability but rather how they perceive it. For example, they may view their achievement of a grade of "B" as less than satisfactory while their boy classmate views the "B" as a good score in the course. Rittmayer & Beier (2009) imply that this may result in lower confidence in the girl and higher confidence in the boy. Rittmayer & Beier suggest that vicarious experience and social persuasion are powerful tools to increase self-efficacy in girls, and that it is vital that female educators have high self-efficacy concerning their abilities to implement integrated STEM if they are to effectively impact female as well as male students adequately .

Self-efficacy is goal-directed and therefore affects the goals an individual sets for themselves. When setting these goals, individuals with higher self-efficacy adopt a greater commitment to the goals, indicating more effort expended and greater persistence when difficulties arise (Rittmayer & Beier, 2008). Thus, it is important to gauge and improve teacher self-efficacy related to integrated STEM in order to result in rigorous goals being set for the curriculum.

As the evident by research conducted, the efficacious views a teacher holds directly affects their implementation and therefore their students' achievement. Thus, it is important to continue studying the contributing factors to teacher efficacy in order to make the necessary efforts to improve the effects.

Methodology

The purpose of this study was to investigate how the attitudes held by elementary teachers affects their self-efficacy and in turn their willingness and confidence in delivering integrated STEM instruction in the elementary classroom. To conduct the research, the researcher developed and distributed the STEM Efficacy Survey Instrument. This survey was first piloted to a sample of teachers from a parochial school in Dallas, TX in order to determine the reliability and validity of the instrument. After being piloted, the researcher created a pool of randomly selected elementary teachers in the Northwest Arkansas area (Benton and Washington Counties) to distribute the survey to. The instrument accepted responses for a two week period of time from this pool of teachers. The survey was intended to address the following research questions:

1. How does teacher self-efficacy affect the implementation of STEM in the classroom?
2. To what extent does formal training in STEM affect teacher self-efficacy related to STEM?

Participants

The researcher first chose to pilot the study to a small sample of 7 teachers from a parochial school in Dallas, TX. These teachers were a part of a convenience sample as the researcher attended this elementary school and was familiar with the participants. These participants remained anonymous.

For the core research, the research focused on elementary teachers in the Northwest Arkansas area. After receiving approval from The University of Arkansas Institutional Review Board, the researcher began creating the pool of participants (see Appendix A). In order to maintain the confidentiality of participants, the researcher gathered a random pool of 100 K-6 teachers currently employed in elementary teaching positions in Benton and Washington Counties in Arkansas.

This pool was formed from the contact information available on the Fayetteville School District and Bentonville School District online directories. To select the random pool, the researcher selected 50 contacts from the Fayetteville District and 50 contacts from the Bentonville District, in order to have 100 names selected. In order to determine how many names to count in between chosen contacts, the researcher added up all the contact addresses in each district and divided the total by 50. This resulted in choosing every 25th name. Additionally, when choosing the participants, the researcher performed eliminations of participants that did not fit the demographics. Such eliminations were substitutes, physical education teachers, high school educators, any educators over 6th grade, and any teachers from non-specified junior highs. When performing these omissions, the researcher would choose the nearest elementary teacher to the rejected name and then continue counting to form the random pool.

Once the pool was formed, the STEM Efficacy Survey Instrument (See Appendix B) was sent via email to all participants along with an informed consent letter that stated that participation was completely voluntary and anonymous. The informed consent letter can be found in Appendix C.

AS the instrument was sent to a random pool from multiple schools, the researcher is presuming that the different schools the participants are employed at have varying levels of STEM implementation. The survey instrument called upon participants to answer demographic questions about themselves and to respond to survey questions about integrated STEM implementation, their educational background, professional development experiences related to integrated STEM education, as well as their perceived levels of confidence in teaching integrated STEM education.

Data Collection

The STEM Efficacy Survey Instrument was used to collect the data. The survey utilized a Google Form that allowed for anonymous responses in order to protect the identity of each participant. Additionally, this Google Form required participants to login in order to ensure each participant only submitted one response. This login did not compromise the confidentiality of the survey. After participants submitted their responses, all survey responses were stored on a password protected account until the assigned research window had closed.

The STEM Efficacy Survey Instrument focused on teacher demographic information such as experience and previous training, teacher attitudes towards implementation of STEM, and the instructional tools used for implementation. The instrument, found in Appendix B, consisted of twenty questions and a combination of multiple choice questions, write-in questions, and questions designed using a 5-point Likert-type range. In this range, participants answered using a scale that ranged from “1” as “strongly disagree”, a “3” as “undecided”, and a “5” as “strongly agree”. Once collected, the data was analyzed using Microsoft Excel. The questions that utilized multiple choice and the Likert range were scored, while the write in data was grouped into categories.

Through the STEM Efficacy Survey Instrument, the researcher was able to gather the information needed in order gain insights into the two research questions. Once the data was gathered, the researcher was able to analyze the results in order to draw conclusions about the information collected.

Results

This chapter provides an analysis of the data collected from the two surveys associated with this study. The purpose of this study was to explore the potential link between elementary teachers’ opinions about STEM education and their implementation of it.

The data for this research was collected from participant responses to the STEM Efficacy Survey Instrument. This research instrument was a 24 question survey. The first ten questions asked demographic questions such as gender, age, teaching experience, education received, and potential training in STEM education. The next four questions inquired about the implementation of STEM into the classroom. Finally, the last ten questions were on a Likert-type range and asked participants to answer questions about their opinions towards STEM education.

This survey instrument was administered to two separate populations which then formed the two data sets that were analyzed throughout the research. The first data set collected was from a pilot-test sent out to a convenience sample of teachers from Dallas, TX. The purpose of the pilot-test was to gain insights into the reliability and validity of the survey instrument. The second set of data collected was comprised of the responses from a pool of elementary teachers in Northwest Arkansas.

Pilot-Test Results

The pilot-test for this research was sent to a pool of teachers from a parochial school in Dallas, TX who had previously agreed to participate. The purpose of this pilot-test was to determine the reliability and validity of the survey instrument. For this reason, the sample chosen was a convenience sample as the researcher had personal connections to the school. The survey was sent via email to the selected participants.

The survey was opened for responses on Wednesday January 20, 2021, and was closed to responses on Friday January 29, 2021. During this time, seven female participants completed the questionnaire. These participants currently teach kindergarten through 3rd grade and all teach a combination of subjects.

The results of the seven teachers' demographic section of the survey are listed here. Of these respondents, there was one 20-30 year old who has a bachelor's degree, 4-10 years of teaching experience, and previous training in STEM in both university courses and professional development. There were two 50-60 year old participants who have bachelor's degrees, over 20 years of teaching experience, and have completed professional development pertaining to STEM. There was also a participant over 60 years old with a bachelor's degree, over 20 years of teaching experience, and professional development pertaining to STEM. Finally, there were three 40-50 year old participants with varying teaching experience. One has over 20 years with a bachelor's degree and professional development pertaining to STEM. Another has 11-20 years of experience, a master's degree, and has completed no training or professional development pertaining to STEM. Finally, the last participant has a master's degree, 1-3 years of teaching experience, and has completed professional development pertaining to STEM. Charts containing the data of the respondents previous STEM training can be seen in Figure 1 and Figure 2.

Figure 1.

Pilot-Test Response to Question 9

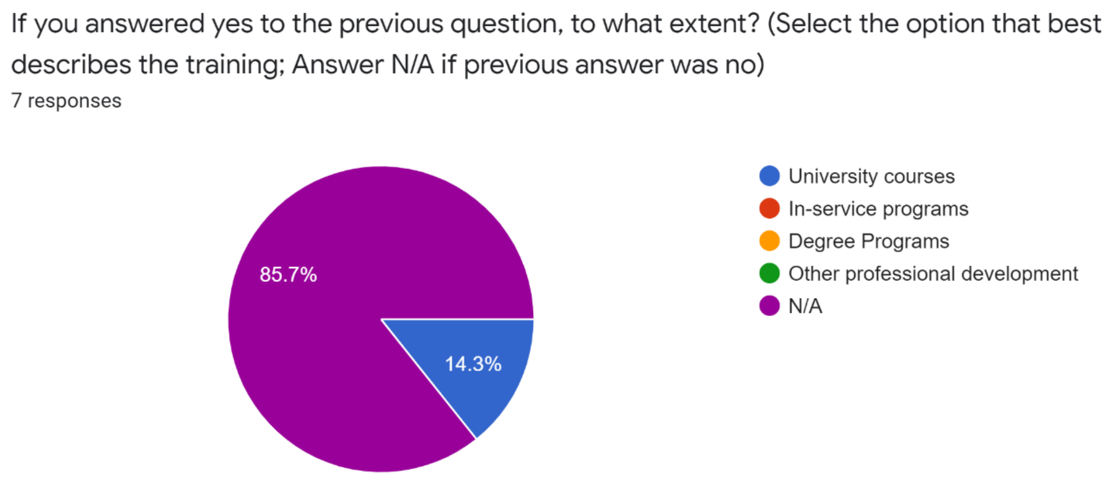
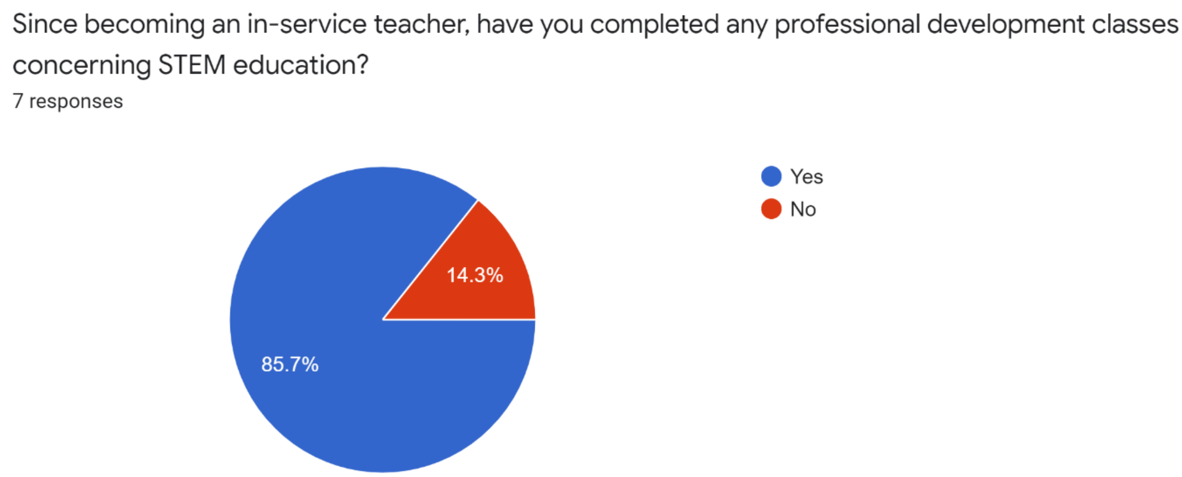


Figure 2.

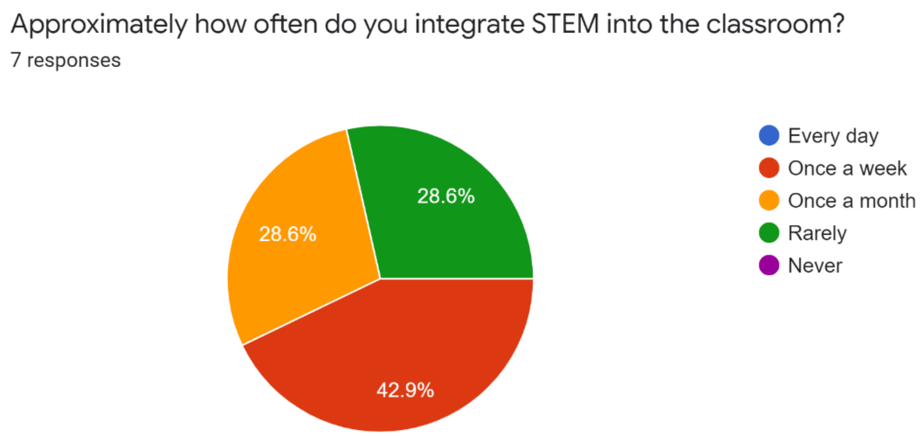
Pilot-Test Response to Question 10



After completing the demographics questions, the participants went on to answer the remainder of the questions pertaining to the implementation of STEM. None of the respondents currently teach an Integrated STEM Curriculum. However, they still incorporate STEM into the classroom as seen in Figure 3.

Figure 3.

Pilot-Test Response to 13



As seen in Figure 3, the participants vary in their integration of STEM into the classroom. This is reflected in their answers in the remainder of the survey. Table 1 shows the participants responses to the Likert-type questions.

Table 1

Pilot Test Responses

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
14. I make an effort to continually find better ways to teach integrated STEM in my classroom.	0%	14.3%	14.3%	57.1%	14.3%
15. I am confident in my ability to teach integrated STEM curriculum and activities effectively.	0%	14.3%	28.6%	28.6%	28.6%
16. Even if I try very hard, I am not able to teach integrated STEM as well as some other subject areas.	14.3%	28.6%	0%	42.9%	14.3%
18. I feel confident in my understanding of the engineering design loop	42.9%	42.9%	14.3%	0%	0%
20. I feel confident in my understanding of the problem or project based learning.	0%	28.6%	28.6%	28.6%	14.3%
21. I am comfortable using ill-structured problems (problems with many correct answer) with my students.	0%	14.3%	14.3%	42.9%	28.6%
22. I am confident that I can answer students' questions during integrated STEM lessons and activities.	0%	14.3%	28.6%	42.9%	14.3%
23. I am comfortable not always knowing the answers to the STEM challenges or problems that I present to my students.	0%	0%	14.3%	57.1%	28.6%
24. Problem or project based learning and integrated STEM requires the teacher to present design problems where the solution is unknown. As a teacher, this causes me some anxiety	0%	71.4%	0%	28.6%	0%

After analyzing the results of the pilot-test, all the participants answers were consistent with their teaching experience, previous training, and professional development. Participants that indicated they did not have much training or understanding of STEM or the engineering design process answered the questionnaire consistent with that background. These answers indicated neutral or low confidence levels and sporadic implementation of STEM. The pilot-test showed no outliers or data that would indicate the survey tool was not valid and reliable. Using this data, the researcher concluded from the pilot-test that the survey tool would be valid for the larger study. Therefore, no changes were made to the survey instrument after the pilot-test.

Study Results

After analyzing the results of the pilot-test, the researcher distributed the survey instrument to the pool of previously identified elementary teachers in Northwest Arkansas (Washington and Benton Counties) via email. This email (Appendix D) was sent to 100 participants on February 8, 2021, containing the link to the survey. Follow up emails containing the same content were sent out on February 15, 2021, and February 19, 2021. The survey closed to responses on February 22, 2021. The survey link was emailed to 100 participants and had been completed by 18 participants at the time it was closed.

The results of the eighteen teachers' demographic section of the survey are listed here. Of the eighteen participants, 100% were female with four (22.2%) in the 20-30 age range, four (22.2%) in the 30-40 age range, five (27.8%) in the 40-50 age range, and five (27.8%) in the 50-60 age range. Among the eighteen, there was a distribution of the grade levels they currently teach. This distribution can be seen in Figure 4. Of the eighteen, fifteen (83.3%) respondents received their master's degree as their highest education, two (11.1%) received their bachelor's degree, and one (5.6%) in the process of completing her master's degree at the time of the survey. Of these eighteen, twelve (66.7%) did not receive formal STEM training as a preservice teacher while six (33.3%) did. Similarly, thirteen (72.2%) of the respondents had completed professional development concerning STEM education since becoming an in-service teacher while five (27.8%) had not. Charts containing the data of the respondents previous STEM training can be seen in Figure 5, Figure 6, and Figure 7.

Figure 4.

Participants Grade Level

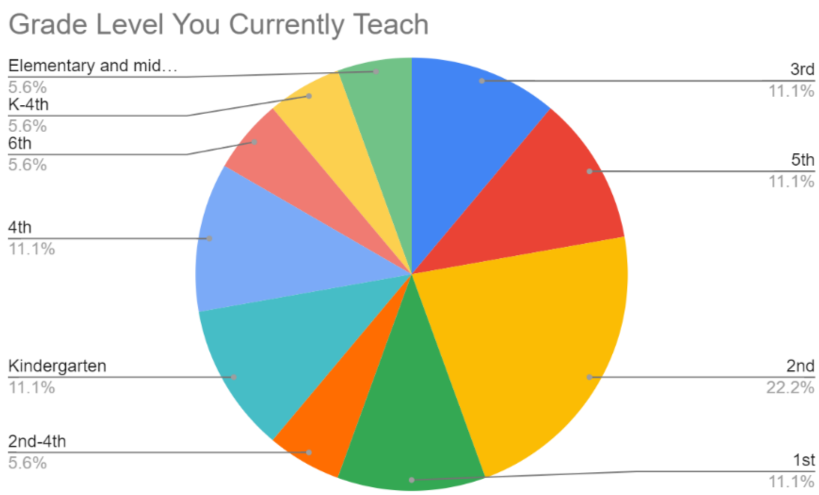


Figure 5.

Study Response to Question 8

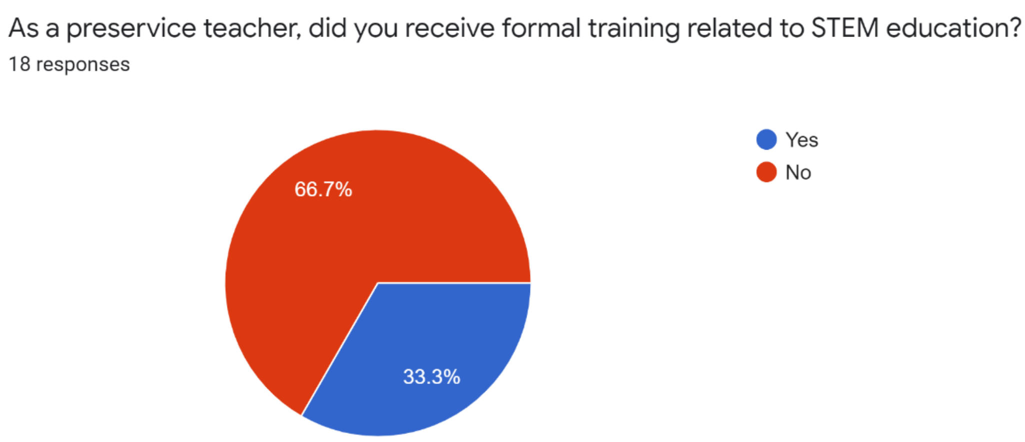


Figure 6.

Study Response to Question 9

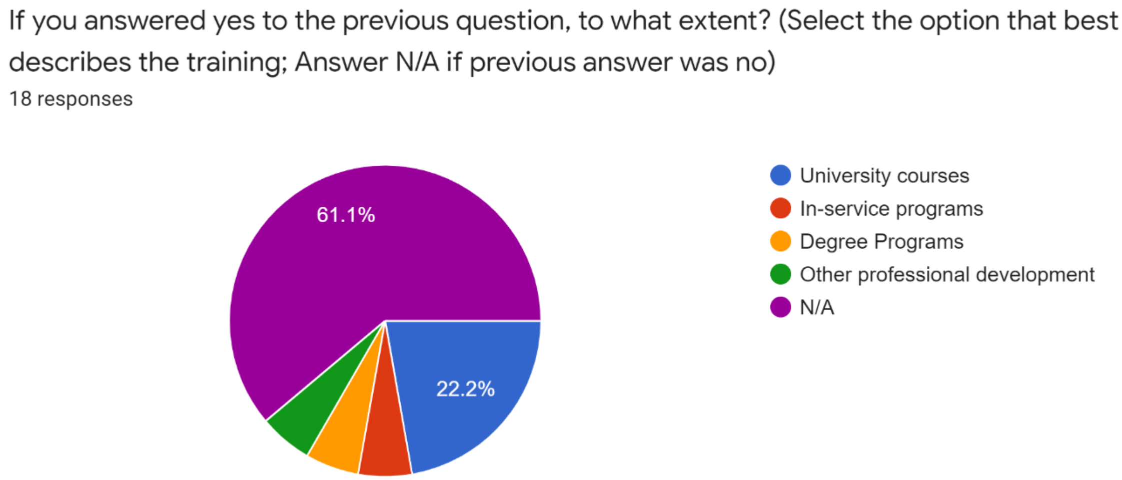
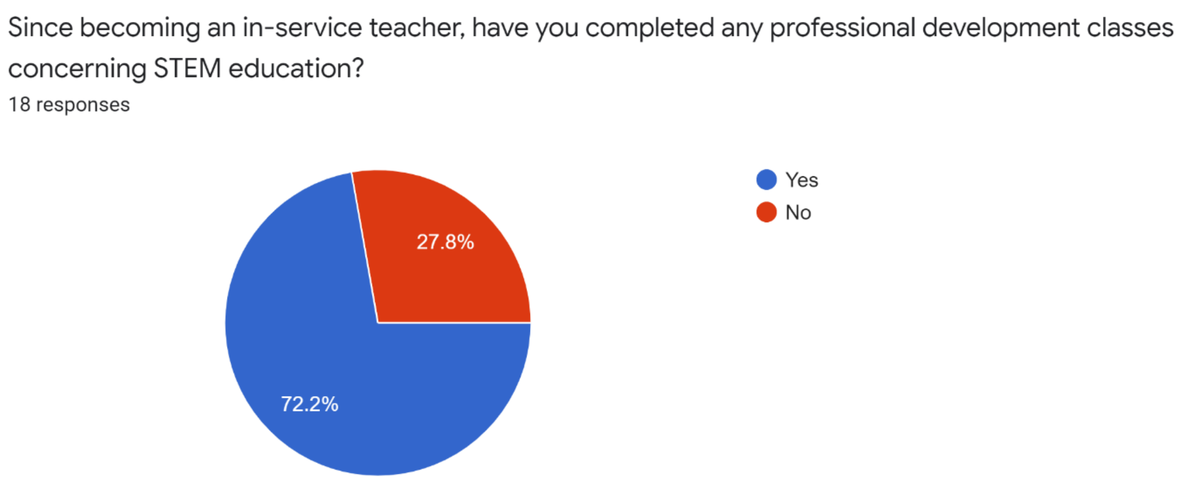


Figure 7.

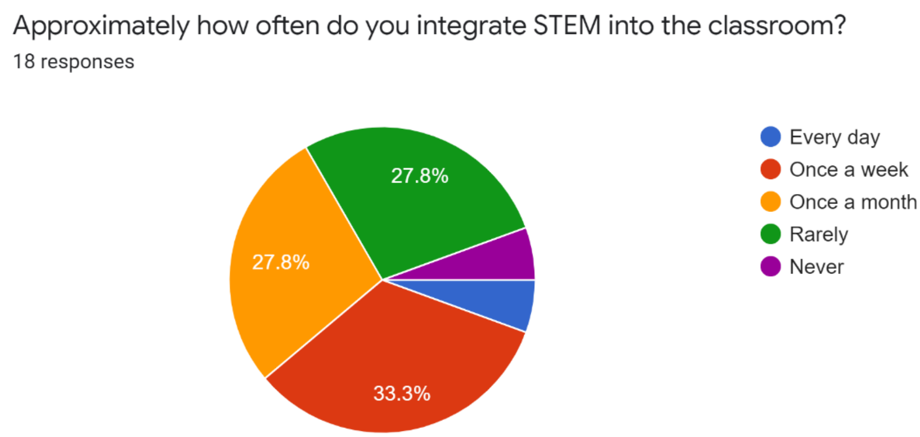
Study Response to Question 10



After completing the demographics questions, the participants went on to answer the remainder of the questions pertaining to the implementation of STEM. Five (27.8%) of the respondents taught an Integrated STEM Curriculum, while thirteen (72.2%) did not. However, the majority of the respondents indicated that they still incorporated STEM into the classroom as seen in Figure 8.

Figure 8.

Study Response to Question 13



As seen in Figure 8, the participants varied in their integration of STEM into the classroom. The respondents answers for their varying backgrounds in STEM education and their varying integration was reflected in their answers in the remainder of the survey. Table 2 shows the participants responses to the Likert-type questions.

Table 2

Study Responses

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
14. I make an effort to continually find better ways to teach integrated STEM in my classroom.	11.1%	0%	61.1%	22.2%	5.6%
15. I am confident in my ability to teach integrated STEM curriculum and activities effectively.	11.1%	16.7%	33.3%	22.2%	16.7%
16. Even if I try very hard, I am not able to teach integrated STEM as well as some other subject areas.	5.6%	33.3%	33.3%	16.7%	11.1%
18. I feel confident in my understanding of the engineering design loop	38.9%	27.8%	11.1%	5.6%	16.7%
20. I feel confident in my understanding of the problem or project based learning.	0%	16.7%	27.8%	33.3%	22.2%
21. I am comfortable using ill-structured problems (problems with many correct answer) with my students.	0%	5.6%	22.2%	44.4%	27.8%
22. I am confident that I can answer students' questions during integrated STEM lessons and activities.	0%	22.2%	27.8%	33.3%	16.7%
23. I am comfortable not always knowing the answers to the STEM challenges or problems that I present to my students.	0%	11.1%	22.2%	38.9%	27.8%
24. Problem or project based learning and integrated STEM requires the teacher to present design problems where the solution is unknown. As a teacher, this causes me some anxiety	5.6%	38.9%	38.9%	11.1%	5.6%

After examining the initial results of the study, the researcher was able to closely analyze the participants responses. Through this analysis, points of discussion and implications can be drawn from the participant responses in order to answer the guiding questions of the research.

Discussion

This study aimed to explore educator's backgrounds in STEM training, their attitudes towards STEM education, and their actual implementation of STEM education. Through the use of the *STEM Efficacy Survey Instrument*, the researcher was able to gain insights into these topics from the participant responses. This chapter discusses the results gained from the participant responses.

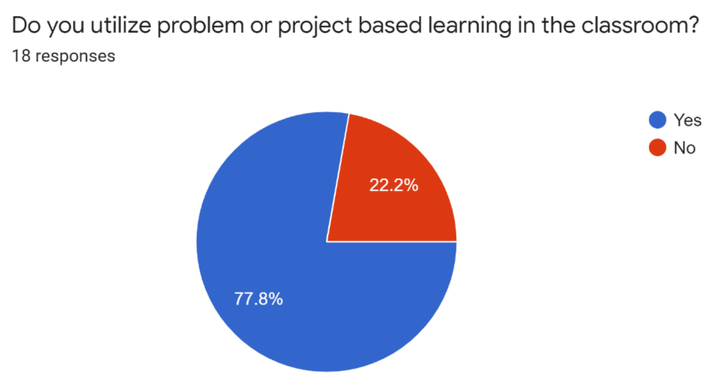
Problem-Based Learning

Problem-based learning is an essential approach to STEM education and the engineer design loop. This learning is comprised of ill-structured learning challenges where more than one outcome can occur. The survey instrument asked teachers multiple questions concerning problem-based learning in order to gain insights into the participants attitudes towards it.

When asked if they used problem or project based learning in the classroom, the majority of both groups of participants responded yes. In the pilot-test, five (71.4%) participants responded that they used PBL while two (28.6%) did not. Similarly, in the study, fourteen (77.8%) responded that they used PBL while four (22.2%) responded that they did not. This response can be seen in Figure 9.

Figure 9.

Study Responses to Question 19

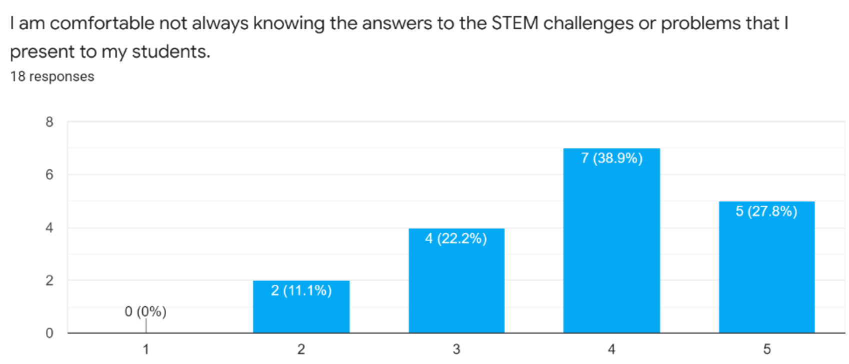


Once participants answered whether or not they utilize PBL, they went on to answer questions about what attitudes they felt towards utilizing PBL. When asked if they felt confident in their understanding of PBL, over half answered confident or very confident. Similarly, over 70% of the participants answered that they felt comfortable using ill-structured problems with their students. These responses showed that the teachers were comfortable using PBL in the classroom.

One of the components of PBL is posing questions that may have many right answers. Therefore, teachers may be presented with questions or responses that they do not always know how to answer. Questions 23 and question 24 in the survey dealt with this idea. Question 23 asked teachers if they were comfortable with not always knowing the answers to the STEM challenges they present to students. As a teacher, it can be uncomfortable or unnerving to not know all the answers. For this reason, the researcher assumed that most teachers would respond that this makes them uncomfortable. Surprisingly, over half of the respondents responded that they were not uncomfortable with this. These responses can be seen in Figure 10

Figure 10.

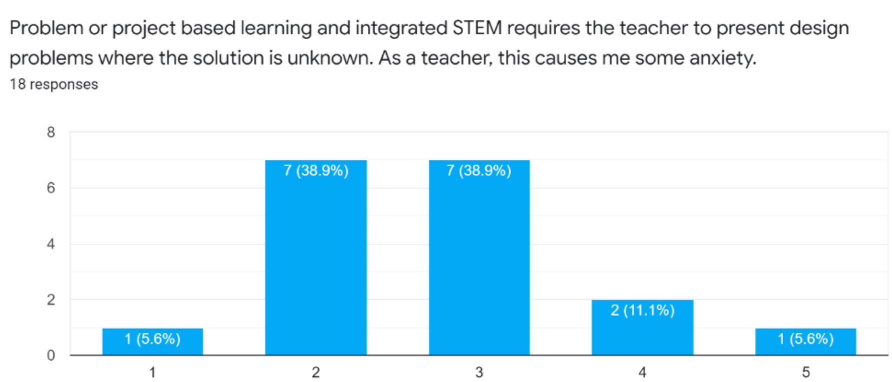
Study Responses to Question 23.



Similarly, question 24 asked teachers whether presenting design problems where the solution is unknown causes them anxiety. Again, the researcher presumed that participants would respond that this would cause them anxiety. However, the majority of the participants responded neutrally or indicated that it did not cause them anxiety. These responses can be seen in Figure 11.

Figure 11.

Study Responses to Question 24



After examining the responses towards PBL, the researcher concluded that the teachers were generally confident and comfortable utilizing PBL in the classroom. As PBL is a great way to integrate STEM, this finding was encouraging as the more confident teachers are, the more likely they are to integrate STEM.

Engineering Design Loop

When examining the responses to questions about PBL, the teachers seemed to exhibit a strong understanding and a high level of confidence. As PBL is an integral STEM technique and a great way to integrate the engineering design loop, the researcher assumed that those confidence levels would carry over to responses regarding the engineering design loop. However, this was not the case.

When asked if they utilized the engineering design loop in the classroom, thirteen (72.2%) of the respondents responded no, and only five (27.8%) answered yes. Moreover, in both data sets, there was a high result of “strongly disagree” when asked about the understanding of the engineering design loop. This was the only question in the entire survey that received more than one “Strongly Disagree” response. This was striking as most of the responses to the survey tended to be more neutral with the majority of the answers being in the 2-4 range. Likewise, in the Pilot-test results, no respondent answered “Agree” or “Strongly Agree.” These responses can be seen in Figure 12 and Figure 13.

Figure 14.

Study Responses to Question 17 about the Engineering Design Loop

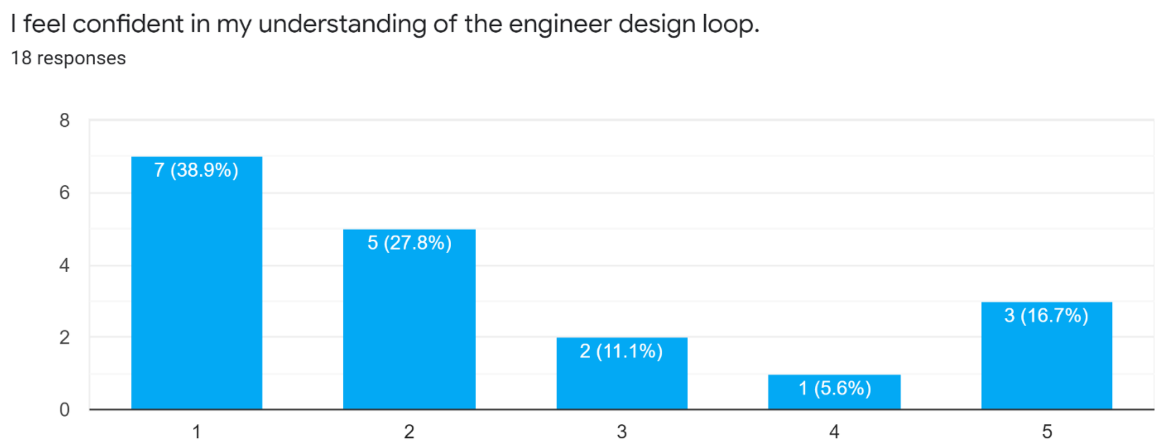
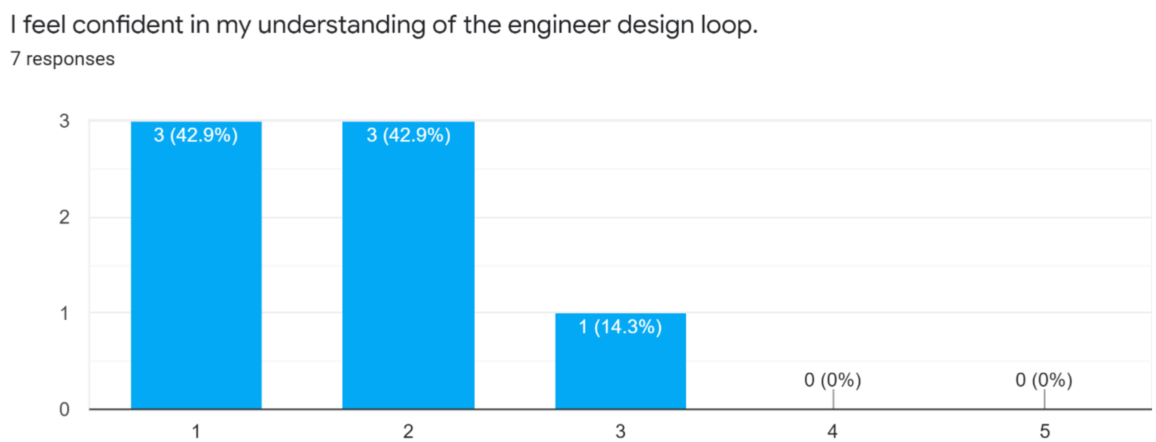


Figure 15.

Pilot Test Responses to Question 17 about the Engineering Design Loop



These strongly negative responses may point to challenges in implementing STEM in the elementary classroom. As respondents indicated that they were not confident in their understanding of the engineering design loop, they also indicated they did not use it. By increasing exposure and understanding of the engineering design loop, STEM implementation would likely increase.

The Link Between Self-Efficacy and Implementation

The primary purpose of this study was to explore the link between teacher training, self-efficacy, and actual implementation. Through exploring the participant responses, the researcher was able to draw conclusions about this potential link.

The majority of the teacher respondents that completed the survey indicated that they had some limited training in STEM, whether this training occurred in pre-service teacher education or as an in-service teacher. This training opened the door for STEM integration as the majority of the respondents indicated that they do integrate STEM approximately once a week.

Additionally, the results indicated that the teachers with the most formal STEM training exhibited the most confidence in their STEM integration abilities. For example, as a pre-service teacher, Respondent 5 had received formal STEM training from a degree program as well as completing professional development since becoming an in-service teacher. After answering these questions about training, the respondent indicated that she generally integrated STEM in her classroom once a week. She also indicated that she continually found better ways to teach integrated STEM in the classroom and that she was very confident in her ability to teach integrated STEM.

On the other hand, Respondent 12 indicated that while she did not receive formal training as a pre-service teacher, she had completed professional development as an in-service teacher. When asked to briefly describe the major characteristics of STEM, this respondent wrote “The major characteristic would be a way of combining STEM (science, technology, engineering, math) into one unit/lesson within the day or week. This is very difficult given the lack of training, the rigidity of our time and schedule, and a complete lack of resources." She then went on to answer that she rarely integrates STEM. Her answers reflect a lack of confidence in the integration of STEM. In this participant's answer, she confirmed the idea of this study that lack of training is a substantial barrier to STEM integration.

As a general conclusion, the teachers that had previous training in STEM were more confident in their ability to implement STEM in the classroom. This conclusion was consistent with the expected results of the study. However, the study results indicated that there are still points of improvement for those teachers as many still were not confident in the engineering design process. Therefore, even though there were higher efficacious views, there are still areas where teachers could form stronger understanding and confidence.

Limitations

A few of the factors that limited the effectiveness of this study were the unprecedented COVID-19 pandemic, small sample size—which was also impacted by the pandemic, potential response bias, and a clear need for further research.

The time period at which the survey was open to responses, COVID-19 was affecting schools and teacher work-load in the schools where the survey was implemented. Along with the unprecedented times of the pandemic, Northwest Arkansas was experiencing an abnormal winter storm that led to power outages. The researcher believes that these two abnormalities may have attributed to the lower than expected response rate.

After the pilot-test was issued, one of the participants shared in discussion with the researcher that it was difficult to answer questions like the ones in the survey as they require one to be introspective and honest. When answering questions and self-reporting, there is always a risk present as it requires the respondent to interpret the question, understand what it is asking, and then answering the question (Widhiarso, 2014).

Additionally, self-reporting poses a risk that respondent may have response bias. As discussed by Peter Smith, "Response biases occur when respondents complete rating scales in ways that do not accurately reflect their true responses. They occur especially among responses to Likert scales that ask the respondent to agree or disagree with various statements" (Smith 2014). For this reason, the researcher suggests that readers analyze the study results with scrutiny as respondents may have exaggerated responses to the Likert scale questions.

This response bias may also occur due to the way females perceive their ability. As studies have shown, girl's and women's confidence in STEM does not always have to do with their actual ability but rather how they perceive it (Rittmayer & Beier, 2009). Therefore, because all the participants in this study were women and because girls and women are more likely to hold low efficacious views towards STEM, the participants may reflect their attitudes but not their actual ability. While they may not feel confident about certain STEM subjects, there is a possibility that their abilities may be stronger than they realize.

Finally, the study sought to examine the link between teacher preparation, such as university courses and professional development, and the self-efficacy teachers have towards implementing STEM. However, as stated in prior research, a person develops their attitudes and efficacious views towards STEM at a young age (Daugherty & Carter, 2017; Lubienski et al., 2013). Therefore, it would be imprudent to assume that a teacher's efficacious views are formed solely due to their teacher preparation which presumably occurs in their 20s, well after their interest levels have been established. Therefore, while this study examines the intended research questions, it may not provide a comprehensive picture of how self-efficacy is formed and the effects it has on STEM implementation.

With these limitations in mind, the researcher can more clearly evaluate the data collected from the study. Additionally, the researcher can make recommendations using the data collected.

Recommendations

After looking at the results and limitations of the study, the researcher proposes several recommendations for further training and research on the effects that teacher self-efficacy has on STEM implementation. AS research points to the positive effects that STEM interventions can have on students, it is vital to explore this link in order to develop effective STEM interventions (Claymier, 2014; Dejarnette, 2012; Havice, 2015; Smithsonian, 2016).

Recommendations for Teachers

After examining the data from the participant responses, the researcher recommends more exposure to STEM curriculum with the intention of increasing self-efficacy. As discussed by Rittmayer and Beier, there are four primary sources that a person’s self-efficacy is based on: mastery experiences, vicarious experiences, social persuasion, and physiological reactions (2008).

One of the participants answered that a barrier for them for STEM integration was “a complete lack of resources.” By increasing exposure to STEM curriculum and opportunities for mastery experiences, teachers will likely feel more equipped to integrate STEM. Another one of the most significant pieces of data were the responses pertaining to the engineering design loop.

The majority of the participants responded that they did not utilize the engineering design loop and were not confident in their understanding of the design loop. The research seems to suggest that interventions or training programs should be developed to inform teachers of the concepts of the engineering design loop in order to increase that understanding. By doing this, the utilization of the engineering design loop will likely increase.

Recommendations for Further Research

One of the major limitations of the study was the small return rate. The researcher recommends that the survey be redistributed at a different point in time in hopes of receiving more responses. Additionally, this study was distributed to a random pool of teachers across the Northwest Arkansas area. Using this pool was decided on to reach a diverse audience, ensure anonymity, and due to the fact that the researcher was not in a classroom placement. This diverse and random pool served the first two purposes. However, without the personal connection, participant pool was less responsive to the researcher’s emails. For this reason, the researcher recommends distributing the survey to a pool where there are higher incentives to respond in hopes of receiving higher rate of response.

As discussed in previous research, the STEM field is heavily male dominated field with women making up only 28% of the workforce (Lubienski et al., 2013). As women tend to hold lower efficacious views towards STEM, the researcher hoped to see how male responses to the survey may have varied from female respondents (Lubienski et al., 2013; Rittmayer & Beier, 2009). Even though the researcher purposefully included male contacts on the participant list, 100% of the respondents were female. For this reason, the researcher suggests re-issuing this study with a larger sample of male educators to compare their responses to their female colleagues.

Finally, as the research shows that efficacious views may not always be reflective of actual ability, the researcher suggests a two-part study. In this study, teachers would complete the survey about their views towards STEM. The study would then observe and analyze the teachers implementing STEM in the classroom. This would provide an interesting view of how a person's views of their ability reflect their actual performance.

From the data collected throughout this study, the researcher produced the previous recommendations in an effort to advance this study. Using the data collected, the researcher drew conclusions where immediate interventions can be made along with further research that can be conducted.

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Appendix A: IRB Approval

UNIVERSITY OF ARKANSAS

To:	Caroline Rene Buechel
From:	Douglas J Adams, Chair IRB Expedited Review
Date:	01/26/2021
Action:	**Exemption Granted**
Action Date:	01/26/2021
Protocol #:	2101307040
Study Title:	An Investigation of the Effects of Self-Efficacy on STEM Implementation

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 109 MLKG Building, 5-2208, or irb@uark.edu.

cc: Michael Daugherty, Investigator

Appendix B: Survey Tool

STEM Efficacy Survey Tool

1. Gender
    a. Female
    b. Male
    c. Prefer not to say
2. Age range
    a. 20-30
    b. 30-40
    c. 40-50
    d. 60+
3. Grade you currently teach: (write in question)
4. Subjects you currently teach: (write in question)
5. Type of district where employed
    a. Urban
    b. Suburban
    c. Rural
    d. virtual
6. Years of Teaching Experience
    a. 1-3
    b. 4-10
    c. 11-20
    d. 20+
7. Highest Level of Education Received (write in question)
8. As a preservice teacher, did you receive formal training in STEM education?
    a. Yes
    b. No
9. If you answered yes to the previous question, to what extent? (Answer N/A if previous answer was no)
    a. University courses
    b. In-service programs
    c. Degree programs
    d. Other professional development
    e. N/A
10. Since becoming an in-service teacher, have you completed any professional development classes concerning STEM education?
    a. Yes
    b. No
11. Briefly describe what you believe Integrated STEM looks like in the classroom (write in question)
12. Do you currently teach an Integrated STEM curriculum?

    a. Yes
    b. No
13. Approximately how often do you integrate STEM into the classroom?
    a. Every day
    b. Once a week
    c. Once a month
    d. Rarely
    e. Never
14. I make an effort to continually find better ways to teach integrated STEM.
    a. Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree
15. I am confident in my ability to teach integrated STEM curriculum and activities effectively.
    a. Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree
16. Even if I try very hard, I am not able to teach integrated STEM as well as some other subject areas.
    a. Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree
17. Do you utilize the engineering design loop in the classroom?
    a. Yes
    b. No
18. I feel confident in my understanding of the engineering design loop.
    a. Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree
19. Do you utilize problem based learning in the classroom?
    a. Yes
    b. No
20. I feel confident in my understanding of the problem based learning. *
    a. Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree.
21. I am comfortable using ill-structured problems (problems with many correct answers) with my students
    a. Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree.
22. I am confident that I can answer students' questions during integrated STEM lessons and activities.
    a. Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree.
23. I am comfortable not always knowing the answers to the STEM challenges or problems that I present to my students.
    a. Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree.

24. Problem based learning and integrated STEM requires the teacher to present design problems where the solution is unknown. As a teacher, this causes me some anxiety.
    a. *Please indicate the degree to which you agree or disagree with each statement. A 1 indicates strongly disagree, a 3 undecided, and a 5 strongly agree.

Appendix C: Letter of Consent

An Investigation of the Effects of Self-Efficacy on STEM Implementation

Researcher:

Caroline Buechel

Michael Daugherty, Ed.D., Faculty Advisor

University of Arkansas

College of Education and Health Professions

Description: The present study, *An Investigation of the Effects of Self-Efficacy on STEM Implementation,* is an honors thesis project designed to investigate how the attitudes held by elementary teachers affects their self-efficacy and in turn their willingness and confidence in delivering STEM instruction in the elementary classroom. The participants will be given a survey on Google forms that should take approximately 10-15 minutes to complete. After completing the survey, the website will email their responses to the researcher.

Risks and Benefits: There are no foreseen risks to participating in this research. The potential benefits include participants enhancing knowledge about themselves and about the necessary steps to increase STEM implementation.

Voluntary Participation: You will participate in a short survey about your attitudes towards STEM education. Participation is completely voluntary.

Confidentiality: Names will not be requested. All survey responses will be anonymous.

Right to Withdraw: Participation is voluntary, refusal to participate will involve no penalty and the subject may discontinue participation at any time.

*If you have any questions or concerns about this study, you may contact Caroline Buechel by email at <crb034@uark.edu> , or Dr. Michael Daugherty by email at mkd03@uark.edu.

If you have questions or concerns about your rights as a research participant, please contact Ro Windwalker, the University's IRB Compliance Coordinator, at 479-575-2208 or irb@uark.edu.

Appendix D: Email to Participants

Hello,

My name is Caroline Buechel and I currently an Elementary Education major and a senior at the University of Arkansas completing my Honors Thesis. For my research, I am examining the link between STEM education in schools and teachers' attitudes towards it. To help me with my research, I am asking that you complete my short survey.

Because you are K-6 teachers in Northwest Arkansas, I obtained your emails through the information posted on your district website and I am inviting you to participate by completing the attached survey. **The survey is in the form of a Google form and can be accessed through this link: https://forms.gle/niJQobQPLTw96BCn8. Please complete the survey by February 22.**

The survey is about 20 questions long and should take approximately 10-15 minutes to complete. Participation is anonymous and voluntary, but greatly appreciated. Attached is a letter of informed consent containing contact information and explaining the minimal risks and purposes of this study.

I look forward to receiving your responses.

Thanks in advance,
Caroline Buechel