Elementary Teacher Self-Efficacy with Design-Based Learning in Virtual and Blended Educational Settings

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ABSTRACT

The research presented in this study investigates the effect of the COVID-19 pandemic on teacher self-efficacy with delivering design-based learning to elementary students and identifies what resources and support teachers need to administer online or blended learning delivery of design-based learning with elementary students in the current environment. The population was elementary teachers teaching STEM content and this study included a sample of four elementary STEM teachers teaching in rural and suburban communities. Each participating teacher completed the Teacher Efficacy and Attitudes Toward STEM Survey (T-STEM) (Friday Institute for Educational Innovation, 2012) to reveal their overall self-efficacy with delivering STEM content, followed by participating in a semi-structured interview consisting of queries targeting both research questions. This qualitative analysis revealed a temporary decrease in teachers' self-efficacy at the beginning of the shift to a virtual environment. A lack of student access to resources at home, the teachers' lack of control and support for the student in a synchronous manner, and a change in STEM education as a priority were revealed as contributors to this temporary decrease in the teachers' self-efficacy. To remediate this, teachers reported condensing activities and the Engineering Design Process to accommodate the virtual environment for a traditionally hands-on instructional strategy. Teachers cited fellow educator support, previous coursework, additional time, and access to teacher resources as resources and support that would be beneficial in the current environment.

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GENERAL AUDIENCE ABSTRACT

The research presented in this study investigates the effect of the COVID-19 pandemic on teacher self-efficacy, or confidence, in using an instructional approach to STEM education with elementary students and identifies what resources and support teachers need to use this instructional strategy online or in blended learning settings, a combination of both online and in-person education. The instructional strategy, design-based learning, allows students to use design-thinking to apply the knowledge they are learning to a construct (Doppelt et al., 2008). This study included a sample of four elementary STEM teachers teaching in rural and suburban communities. Each participating teacher completed the Teacher Efficacy and Attitudes Toward STEM Survey (T-STEM) (Friday Institute for Educational Innovation, 2012) to reveal their overall self-efficacy with delivering STEM content, followed by participating in an interview. Prominent topics, or themes, revealed from the interviews revealed a temporary decrease in the teachers' self-efficacy at the beginning of the shift to a virtual environment at the beginning of the global pandemic. A lack of student access to resources at home, the teachers' lack of control and support for the student in a real-time manner, and a change in STEM education as a priority were revealed as contributors to this temporary decrease in the teachers' self-efficacy. To address this, the teachers reported condensing activities and the Engineering Design Process to accommodate the virtual environment for a traditionally hands-on instructional strategy. Teachers cited fellow educator support, previous coursework, additional time, and access to

teacher resources as resources and support that would be beneficial in the current education system.

DEDICATION

I would like to dedicate this dissertation to my grandfather, George E. Snead, Sr. or "Gacky". He was one of many who inspired me to begin this journey and made it one of his last wishes and dreams during his final days with us. His confidence in me and the gentle reminder of him as I drank from his coffee cup on long days of writing kept me typing on with determination.

I would also like to dedicate this dissertation to my family and friends who held my hand along the way. It was your words of encouragement, your pride and your steadfast examples that led me to the end of this journey. I thank you immensely.

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Chapter 1: Introduction

Educational Context

In today's education system, teachers are turned continuously in new directions to improve their teaching effectiveness to match our workforce's future demands (Robinson, 2013). This same education system continually assesses students to track their mastery of statewide and national content standards. Assessments shift from strictly multiple-choice content-based questions to more critical thinking questions that require an application of content (VDOE, 2014). While the assessments change, teachers must shift their pedagogical practices to provide students with higher-order thinking skills essential for the 21st century (Parker et al., 2015). As a result, teachers are continually seeking new ideas and teaching practices to help students grasp the concepts needed to pass these assessments and expand the knowledge base for their future.

The emphasized value of Science, Technology, Engineering, and Math (STEM) in all aspects of our society increases the need for STEM literacy among students (Change the Equation, 2012). Traditionally students have been taught STEM disciplines in a siloed approach, limiting the amount of interaction between the four subjects. Students are less likely to see the interconnectivity between the disciplines in a siloed approach, resulting in a weaker knowledge-base of the four disciplines and how they build upon one another. STEM literacy helps to prevent this issue by emphasizing all four disciplines. Not only is STEM literacy necessary for students entering higher education, but it is also essential to begin in young students at the elementary level (Viera & Viera, 2014). This literacy consists of teaching students the importance of each of these fields and showing them why it applies to their everyday lives. It is one thing to teach a student the content, but another to have them apply it in the world around them.

Authentic Integrative STEM education builds on these connections, eliminating the issue of students seeing STEM disciplines as siloed subjects that do not intermingle. Sanders & Wells (2010) define Integrative STEM Education as:

> Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts and practices of technology and/or engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, etc. (Figure 1).

Integrative STEM Education brings purposeful and intentional technology and engineering design-based learning to students to gain authentic experiences with the concepts they are learning (Sanders, 2013). When administered correctly, students can formulate their thoughts on a topic while simultaneously pulling on concepts and skills from the other Science, Technology, Engineering, and Math disciplines.

Design-based learning is one of the pedagogical approaches teachers can use to create critical thinking opportunities for their students through an Integrative STEM approach. Doppelt et al. (2008) define design-based learning (DBL) as:

> DBL enables students to experience the construction of cognitive concepts as a result of designing and making individual, inventive, and creative projects, to initiate the learning process in accordance to their own preference, learning styles, and various skills (pg. 23).

Design-based learning gives students a fully immersive experience with a new idea that allows for interdisciplinary education, giving them an understanding of the interconnectedness of learning across disciplines. Instead of presenting students with the content and requiring memorization to regurgitate the concept, students are interacting with the idea to promote authentic understanding (Fortus et al., 2004). Although teachers may believe their current methods to be sufficient, design-based learning may provide students with additional opportunities to practice and develop 21st-century skills essential in their future endeavors. Teachers must explore the effectiveness of design-based learning and be willing to implement it in their classrooms if students are making academic growth with exposure to this pedagogical method. Teachers must have proper research on the benefits of design-based learning, and they must be prepared to change their current instructional practices if need be to adapt to the changing education system (Parker et al., 2015).

STEM has become a significant talking point in today's education system across all grade levels. Teachers are asked to increase students' exposure to STEM in various forms, whether it be from increasing courses offered in STEM disciplines, integrating STEM concepts into their lessons, or exploring Integrative STEM Education design-based learning. With a drastic swell in the number of jobs demanding a STEM-focused workforce (Change the Equation, 2012), the responsibility to introduce students to STEM is falling into elementary school teachers' hands. These teachers are looking for ways to bring STEM into their classrooms so their students will be able to understand the content in STEM disciplines and develop the 21st-century skills demanded in our future workforce.

In Spring 2020, the global education system experienced a shockwave with regulations and precautions implemented to prevent the spread of Coronavirus Disease 2019 (COVID-19) (Dibner et al., 2020). Schools across the nation went into a virtual format, requiring students and teachers to connect through web-based platforms online, if at all. While task forces address this urgent global pandemic, teachers face the action of building a boat as they sail it in a virtual environment across K-12 education (Dibner et al., 2020). The national shutdown with regulations mostly mandated at the state-level forced school districts to reevaluate their priorities to continue student academics. Occurring during the end of the school year for most K-12 schools, assessments were at the forefront of many teachers' agendas. The U.S. Department of Education worked swiftly to establish guidelines for the Elementary and Secondary Education Act, placing the question of whether or not standardized assessments would continue in the state's hands (U.S. Department of Education, 2020). With the broader education system reevaluating its' approach to education, pedagogical approaches to STEM education across K-12 education became less prominent amongst education discussions.

The research presented in this study intends to explore the changes and present realities in implementing Integrative STEM Education at an elementary level despite whether students are receiving in-person, virtual, or blended instruction. This study analyzes the current status of virtual design-based learning from elementary teachers who have attempted design-based learning in a virtual setting. This study aims to identify the changes in delivering STEM content through design-based learning throughout the stages of the COVID-19 pandemic and gain insight into what teachers need to feel more supported in delivering this instructional strategy virtually.

This study's first research question addresses the effect of the COVID-19 pandemic on teacher self-efficacy with delivering design-based learning to elementary students. Teacher self-efficacy before, shortly after, and currently in the pandemic was identified through teacher interviews. The participating teachers were also be asked to elaborate on how professional development has affected their current self-efficacy with delivering design-based learning in a virtual format, if at all. This research question sheds light on the status of teacher self-efficacy with delivering an instructional strategy typically implemented in a hands-on environment virtually, and how they may have navigated any changes.

The second research question presented in this study aims to identify the resources and support teachers need to administer online delivery of design-based learning with elementary students in the current environment. For teachers to continue delivering this pedagogical approach to STEM education, studies must identify the gaps and how the education system can help teachers navigate them through providing or developing resources and offering support. This research question will also use interviews with teachers who have implemented Integrative STEM Education with their elementary students before the global COVID-19 pandemic.

Justification/Rationale for the Study

Design-based learning provides students with opportunities to build upon their analytical thinking required to contribute to a STEM-centric workforce (Change the Equation, 2012). Through design-based learning, students can plan, collaborate, design, construct, and analyze the topics they are covering (Fortus et al., 2004). The analytical piece to design-based learning with an integrative approach is fundamental in developing higher-order thinking skills. While this pedagogical approach historically takes place in a hands-on environment (Doppelt et al., 2008), the current educational environment demands a shift to virtual approaches for K-12 instruction. Teachers are being asked to push the boundaries and innovate new means to deliver instruction in these unprecedented times (Tsui et al., 2020).

Purpose of the Study

What teachers, particularly elementary teachers, are doing to implement design-based learning in the current environment is mostly unknown, given the rapid change in the education system. Classrooms are now receiving instruction through online or blended learning delivery, potentially affecting whether or not teachers are still using design-based learning in their classrooms. This change may also affect whether or not teachers feel equipped with the tools and knowledge to move forward with this instructional strategy for STEM content in an ambiguous environment. The rapidly changing environment in education creates an opportunity for research waiting for exploration through the new research questions developed in this study. Interviews conducted for this study aim to highlight the changing self-efficacy in teachers' ability to deliver design-based learning in a virtual environment and identify ways they have been able to navigate accordingly. This study will also shine a light on what teachers feel they need to deliver design-based learning adequately in a virtual or blended learning classroom environment.

Definition of Terms

The following terms and definitions provide clarification for the subsequent literature review and study analysis.

STEM Literacy

STEM literacy refers to students' knowledge in STEM disciplines and how they apply to their world. STEM literacy is essential to producing an informed and critical thinking future workforce (National Research Council, 2012). There are various ways to equip students with STEM literacy, but the integrative approach in Integrative STEM Education provides students with opportunities to apply their STEM literacy in real-world challenges (Peterson, 2017).

STEM Education

The emphasis on STEM education, whether taught separately or in an integrated approach, has been a focus of the United States education system for the past 25 years with a move toward more integrative practices (National Science and Technology Council, 2018). For this literature review, STEM education will refer to the broader efforts to increase students' access to instruction and experiences with all STEM disciplines, whether siloed or integrated.

Integrative STEM Education (I-STEM)

Integrative STEM Education (I-STEM) is an approach to STEM education that intentionally integrates technological/engineering design-based learning practices to teach STEM content (Sanders & Wells, 2010). I-STEM education allows for further integration beyond STEM disciplines as students pull on other subject areas for problem-solving to find solutions to real-world challenges.

Design-based learning (DBL)

Design-based learning, or DBL, is an approach to STEM education that allows students to explore content through a robust unit rooted in design where students apply the content they are currently learning to solve an authentic, real-world problem (Doppelt et al., 2008). Design-based learning is an integral part of Integrative STEM Education as students problem-solve through design and creation.

STEM Pipeline

The STEM pipeline refers to the hypothetical pipeline students follow to a future STEM career (Ball et al., 2017). Increasing access to the STEM pipeline and eliminating entry barriers for all K-12 students is emphasized in the education system as the demand for applicants for STEM jobs continues to increase.

Career Choice Development

Career choice development refers to students' development of interest in specific career fields throughout their early life. This literature review will explore factors that lead to students' career choice development and how this may influence students' entry or barriers to the STEM pipeline.

Self-Efficacy

Self-efficacy refers to one's confidence in their ability to complete a task accurately (Bandura, 1977). For this literature review, both student self-efficacy in STEM and teacher self-efficacy in delivering STEM content will be analyzed to provide background information for the subsequent study looking at teacher self-efficacy.

Professional Development (PD)

Professional Development (PD) opportunities allow teachers to expand their knowledge in educational pedagogical practices or content knowledge through workshops, courses, or additional degrees pertaining to a specific field in education.

Chapter 2: Literature Review

This literature review will explore best practices for Integrative STEM Education and design-based learning, dive into the various components to consider when administering professional development in STEM with elementary teachers, and identify research on distance and online education, specifically for teacher professional development. Despite the quality of studies conducted to explore design-based learning, professional development, and distance and online professional development in an elementary context, it is evident that additional studies are needed to address the current demand for administering instruction in an online or blended learning environment to elementary students.

Integrative STEM Education

Student Career Development

The STEM pipeline is a term frequently used to symbolize the path students take throughout their schooling to an eventual career in a STEM field (Ball et al., 2017). Although this pipeline is heavily discussed and emphasized, there remain leaks where students tend to stray from a STEM career (Allen-Ramdial & Campbell, 2014; Ball et al., 2017). Lack of interest in STEM fields is an issue that needs to be addressed by our education system (Tuijl & Molen, 2016) by increasing students' self-efficacy and beliefs toward STEM and STEM careers. Several studies have revealed insight into how students' career choice is formed for STEM fields from various factors (Tuijl & Molen, 2016), determining whether or not students can maintain their path in the STEM pipeline, or become more susceptible to leaking out.

External Factors

When looking at how career choice develops, many factors contribute to a student's success in the STEM pipeline throughout their K-12 education. Among these factors, not all are influenceable. Gender and socioeconomic status (SES) are two external factors students bring with them as they enter the pipeline, influencing their future in STEM (Tuijl & Molen, 2016). While some studies have found fewer differences between elementary female and male students' STEM perceptions (Kurz et al., 2015), Tuijl & Molen (2016) found a significant difference in students' STEM perceptions with different socioeconomic statuses. To address this, we must develop STEM education programs that accommodate all students, especially those historically underrepresented in STEM fields (Allen-Ramdial & Campbell, 2014), and reach all schools by meeting them where they are in the transition, or lack thereof, to valuing STEM education. In looking beyond STEM perception and career interest through K-12 education, we must also acknowledge whether or not these students continue to finish a degree in a STEM field in their undergraduate and graduate studies (Ernst & Bowen, 2014) despite their SES.

Age

In a review of the recent literature on when student career choice develops, there is a significant amount of research demanding further emphasis and exploration in early childhood career choice development (Kurz et al., 2015; Foltz et al., 2014; Wang, 2013; Wang & Degol, 2013; Ball et al., 2017; Colston et al., 2017; Tuijl & Molen, 2016). Foltz et al. (2014) noted that students choose whether or not they wish to pursue STEM in elementary years, emphasizing the importance of equipping teachers with the necessary tools to promote STEM. Students are drawn to technology at this age, one of the key disciplines in STEM, and are susceptible to pursue it as a career (Kurz et al., 2015). In the 1980s, Brusic et al. (1988) touched on the push for technology education in elementary classrooms, showing the education system is still working to increase technology education in elementary years to witness the benefit it produces over thirty years later.

While many studies research the importance of STEM career choice in middle and high school, elementary years are the formative years where we need additional research in STEM career development (Tuijl & Molen, 2016; Wang, 2013; Wang & Degol, 2013). As leaky as it may be, the STEM pipeline kicks off in the elementary years of a child's education (Ball et al., 2017). Tujil and Molen (2015) stress the shift from career choice to focusing on career development, or molding students to think toward the career path they will eventually choose in an elementary setting. Awareness of the choices is the key component to career development in a students' early academic years (Colston et al., 2017). We must continue to direct students toward STEM fields in high school while also allowing students to explore these fields in middle and elementary school (Tuijl & Molen, 2016; Wang, 2013).

Influence

Addressed later in this literature review will be the role outsider influence plays on students' future in the STEM pipeline. When looking at how career choice develops, the question of where it develops from is essential. Family or close friends can drive students' career development during their early academic years (Foltz et al., 2014). These influential factors will be explored more in-depth in the subsequent section on how students accumulate their knowledge of STEM fields' various careers.

Career Choice Theoretical Frameworks

In the early stages of a child's life, children witness behaviors and choices made by the adults surrounding them they could eventually imitate. Bandura (1986) refers to this practice as the Social Learning Theory, in which behaviors are modeled for children who eventually replicate this behavior from memory. This theory thrives on four prominent features, including personal accomplishments, learning through others, learning by others, and physiology (Lent et al., 1994). When looking at students' career awareness and career interests, we must acknowledge the influence of those around them (Lent et al., 1994). Before students enter academics, they witness their parents' or guardians' career paths and choices, ultimately influencing their own.

Based on Bandura's (1986) Social Learning Theory, Lent et al. (1994) labeled the influence of social learning on student's career interests as the Social Cognitive Career Theory (SCCT). This theory analyzes the role of self-efficacy on one's ultimate career path and how modeled behaviors or experiences with others can mold this self-efficacy. Analyzing student's career interests and choices, particularly in elementary school, demands the attention of social influence. The Social Cognitive Career Theory recognizes the influence prior experiences and adult modeling have on a person's career path, reiterating the role of early-age influence on a student's career choice whether they choose to show interest in STEM fields or not.

Student Career Awareness

Out-of-School Influence

As mentioned before, several factors can influence students' knowledge of career choices. Before entering an academic setting, family or close friends' interest in STEM could prompt a student's direction (Foltz et al., 2014). A spark in interest could also occur during a student's time in the K-12 pipeline, but outside of a school setting. For example, Young et al. (2017) conducted a student on Out-of-School Time, finding that factors outside of academics could also positively affect a students' interest in STEM fields. Some of these factors included social, academic, and pre-determined (i.e., gender) variables, which could all at some point pave the way for a student in the STEM pipeline (Young et al., 2017). With that said, many students also lack the out-of-school experiences in STEM fields that could kick start their STEM pipeline journey (Young et al., 2017).

In-School Influence

Once students have entered the educational system, they will likely obtain additional awareness of STEM careers (Brown et al., 2016; Holmes et al., 2018; Wang, 2013; Wang & Degol, 2013). Holmes et al. (2018) conducted a four-year study highlighting the importance of teachers' awareness of students' interest in STEM careers during mathematics instruction to maintain student self-efficacy in STEM. Early elementary experiences in STEM contribute to a students' interest in STEM (Brown et al., 2016) and willingness to pursue undergraduate degrees in STEM disciplines (Wang & Degol, 2013), ultimately retaining a student's spot in the STEM pipeline. Wang (2013) noted mathematics and science instruction as critical determinants in the pipeline. Experiences with authentic integrative STEM in different settings at an early age could also influence students' decisions to pursue STEM careers in the future (Bowen & Peterson, 2018). While out-of-school experiences positively contribute to students' career awareness, the in-school instructional time has proven to influence knowledge of STEM fields.

Combination

Many researchers believe both out-of-school and in-school time influence students' career awareness. Tuijl & Molen (2016) believe both teachers and family members to have profoundly influential roles in students' interest in STEM fields. Exposure to STEM education helps maintain the pipeline (Brown et al., 2016) by keeping students knowledgeable on the various STEM career pathways they could pursue. Holmes et al. (2018) emphasize the range of STEM career predictors, crediting student interest and follow-through to academic achievement, parent occupation, culture, gender, and age. These factors contribute to the challenges and successes students will ultimately face with entering STEM fields (Allen-Ramdial & Campbell, 2014).

Further Research Needed

Among the studies analyzing student interest and awareness of careers, many address the need for further research on improving the STEM pipeline (Honey et al., 2014; Wang, 2013; Wang & Degol, 2013; Young et al., 2017). Honey et al. (2014) dive into the effect of integrated STEM on students' STEM interests, declaring the need for more robust and descriptive studies. Research in STEM interest and career awareness derived from elementary years remains another gap in the research (Wang, 2013; Wang & Degol, 2013). Further research is needed on STEM career awareness at an elementary level and how this can ultimately affect students' academic and career paths in the future.

Synthesis

STEM career development can grow from a variety of factors ranging from pre-determined to externally influential. Bandura's Social Learning Theory (1986) and Lent et al.'s (1994) Social Cognitive Career Theory highlight one's past experiences and childhood influences that could affect career development. Student's parents and adult role-models positively influence their choices at a young age, with career choices as no exception. When looking specifically at the research available for career awareness, few studies explore career awareness in an elementary setting, and even fewer analyzing the primary aged students (K-3) in elementary grades. There are apparent gaps in the research on elementary students' STEM career awareness across all pedagogical approaches to STEM education. Many studies analyze students' interest and self-efficacy in STEM, which contribute to the STEM pipeline, but few address whether students fully understand the scope of careers across the STEM disciplines.

Best Practices in Design-based learning

Integrative Design-based Learning

Design-based learning (DBL) is a pedagogical approach to STEM education in which students apply content knowledge to solve an authentic, real-world problem (Kolodner et al., 1998). Integrative STEM Education relies on technological/engineering design-based learning to allow students authentic experiences by integrating the STEM disciplines and applying their content knowledge to solve a problem. The design component allows students to partake in an iterative process based upon inquiry to find a solution to a real-world problem (Kolodner, 2002; Sidawi, 2009). When applying their content knowledge, creative reasoning in design-based learning is another critical element that promotes student learning (Doppelt, 2009; Lee & Kolodner, 2011). Through design-based learning, students have an opportunity to apply their knowledge to a design challenge, promoting the critical thinking and problem-solving skills demanded in the 21st century (Daugherty & Mentzer, 2008).

Integrative STEM education provides a means to deliver technological/engineering design-based learning by intentionally integrating the STEM disciplines to provide authentic learning experiences for students (Sanders, 2008; Sanders, 2013; Wells, 2013). This approach to STEM education is appropriate across all grade levels, from kindergarten to doctoral students (Sanders, 2013). Sanders (2012) reports Integrative STEM Education as a best practice among STEM education approaches, allowing students to apply problem-solving skills across multiple STEM disciplines in an authentic and meaningful context. Integrative STEM Education aims to fix the STEM pipeline problem by engaging students at a young age with STEM experiences they can remember (Sanders, 2008).

Standards-Based

Design-based learning must be standards-based, depending on the particular school system's standards, to be successful. Intentional integration of content presented in the Next Generation Science Standards (NGSS), National Council of Teachers of Mathematics (NCTM) standards, or the International Technology and Engineering Educators Association (ITEEA) standards, design-based learning can facilitate an environment where students are actively engaged and still learning mandated content. The intentional integration of the standards and content is critical (Wells, 2013). Students must first obtain the content knowledge needed to begin problem-solving (Barak & Zadok, 2009; Bowen et al., 2016). Students without prior content knowledge can still find success in design-based learning after participating in several iterations, so long as the content knowledge is evident throughout the scenario (Bowen et al., 2016). Schematic knowledge obtained through the standards allows students to transfer this knowledge into strategic knowledge with problem-solving capabilities (Wells, 2010). Strategic knowledge is what will ultimately be demanded of students in the future workforce.

Technological/Engineering

Two critical components to design-based learning that serve as the glue to a fully integrative experience are technology and engineering. Technological literacy and technology education are urgently needed (Rossouw et al., 2011), specifically in an elementary setting (Brusic et al., 1988; Rose et al., 2017). Teachers must be well equipped with resources and pedagogical knowledge to accurately educate students in technology education (Cajas, 2001). Regarding engineering, teachers need further clarification on how to best use engineering to support student learning (Guzey et al., 2017). When approaching design-based learning, engineering is a critical discipline in bringing design pedagogy forward (Sanders, 2010). Guzey et al. (2017) found that although adding engineering improved teacher instruction and student learning, intentional integration is vital in providing students with design-based learning opportunities. When looking specifically at elementary teachers, further professional development is needed to equip them with the skillset to implement technology and engineering education, as they typically train in foundational concepts for traditional core subjects (Ernst, Bottomley et al., 2011; Estapa & Tank, 2017; Guzey et al., 2017).

Authenticity and Application

Another crucial feature of implementing design-based learning is authenticity. Wells (2010) clarifies design-based learning as a pedagogical approach allowing students to apply the content knowledge they have acquired in an authentic setting. Design-based learning allows students to take what they have learned and apply it to solve a real-world problem (Fortus et al., 2004), whether that be a local or broader problem. Fortus et al. (2004) emphasize the steps taken during design-based learning through the engineering design process that allow students to develop the skillset needed to problem-solve through design. Bowen and Peterson (2018) found this to be a component of design-based learning that needs further exploration impact student learning. Authenticity allows students to apply their content knowledge to real-world scenarios, but teachers may need further practice in applying authenticity to a design-based learning unit to see an increase in student achievement.

Evidence

When implemented, design-based learning has shown positive results in students' STEM beliefs (Brown et al., 2016; Ugras, 2019), achievement (Doppelt et al., 2008; Kyza & Nicolaidou, 2017), and teacher self-efficacy with the content and pedagogy (Capobianco et al., 2017; Wells, 2017). Brown et al. (2016) conducted a study on student STEM beliefs after exposure to a problem-based STEM curriculum, finding an increase in students' beliefs on whether they felt STEM to be useful. Doppelt et al. (2008) conducted a study on student achievement following a design-based learning unit and found an increase in student concept knowledge following implementation. When looking at teacher professional development in design-based learning, Capobianco et al. (2017) analyzed elementary teacher experiences with engineering Design-Based Science and found a positive result on teacher implementation following professional development opportunities. Wells (2017) also found an increase in teacher understanding following two immersive technological/engineering design-based learning challenges. Although it may take various forms and names, design-based learning is showing positive results in students' and teachers' content knowledge and pedagogy.

Synthesis

Design-based learning is a pedagogical approach to STEM education, allowing students to utilize technological and engineering design-based practices to apply mathematics and science content knowledge. This pedagogical strategy is in practice across the education system, despite the variety of names used to identify it (i.e., Problem-Based Learning, Design-Based Science, design challenges, Learning by Design). Technological/engineering design-based learning emphasizes using standards-based content to give students authentic problem-solving experiences to mitigate real-world problems. Several studies have analyzed the results of design-based learning, showing this to be a beneficial pedagogical strategy that needs further emphasis throughout teacher professional development.

Teacher Professional Development

To increase elementary students' exposure to Integrative STEM Education and design-based learning, teachers need to be well-versed in this instructional strategy and comfortable enough to implement it. The following review of literature in professional development will look at general best practices and the current state of professional development in STEM for elementary teachers by referencing past studies on elementary teacher self-efficacy with STEM.

Professional Development Models

Through the variety of teacher professional development models that have surfaced, a focus on pedagogy has remained consistent throughout successfully implemented PD models (Guskey, 2003; Mishra & Koehler, 2006). A focus on pedagogy and content knowledge allows teachers to understand ‘how’ versus getting a glimpse at ‘what’ (Fullan & Langworthy, 2014). This concentration on pedagogy in professional development models leaves teachers with a deeper understanding of the practice they wish to implement in their classroom and a broader knowledge base on why it is impactful. Interweaving the evidence-based pedagogical practices with teachers’ content knowledge creates positive outcomes for professional development implementation (Guskey & Yoon, 2009; Mishra & Koehler, 2006).

The various methods of professional development must also recognize the audience in which they are addressing. Several recommended models have surfaced from the adult learning theory, including self-directed, incentive, and interactive professional development. For teachers to be engaged, especially in web-based professional development, the principles behind adult learning theory must be applied (Collins & Liang, 2015). The adult learning theory distinguishes the importance of self-directed learning for andragogy (Merriam, 2001). For active participation, teachers need an incentive for motivation achieved through explicitly stated objectives that guide teachers in achieving their final goal, or incentive (Knowles et al., 2011). Teachers also may need hands-on or interactive involvement with the pedagogical practices delivered through PD (Bufkin & Bryde, 1996). For pedagogical practices delivered through a web-based portal, professional development facilitators must be intentional in ensuring the teachers are still able to interact with the material, whether that means interacting with it during the actual PD session in an engaging virtual manner or implementing it in their classroom to allow for reflection or feedback in a future session.

Professional Development Structures

Professional development can be offered in various settings, allowing teachers to build upon their pedagogical toolkit during the school year, summer break, or in a virtual environment due to the limitations of the current education system during a pandemic. Workshops and summer institutes based upon evidence-based strategies mentioned in the next section have proven to produce positive professional development results (Guskey & Yoon, 2009; Estapa & Tank, 2017). Convenience has also been a primary factor in successful professional development implementation, showing teachers as willing to participate in PD that does not interfere with their in-school schedule or personal commitments (Collins & Liang, 2015; Parsons et al., 2019). Whether implemented during the school year or summer break, studies have also shown teachers' face-to-face preferences (Collins & Liang, 2015) or web-based professional development (Kusmawan, 2015) dependent upon social and convenience factors.

Professional development has been implemented through various models that vary significantly in the number of contact hours for completion. While brief PD models are frowned upon, contact hours are not necessarily the most impactful variable in whether or not the implementation of professional development is successful (Kennedy, 1998). Programs ranging from two days (Havice et al., 2018) to over a year (Aldahmash et al., 2019) have proven to be impactful, showing there can be a variation in length without affecting the success of the PD. In an analysis conducted by Kennedy (1998), long-duration PD positively affected teachers' science content, but not necessarily math content. These studies have shown that while duration is an essential factor to consider, it does not determine the success of a professional development model.

Professional Development Strategies

Sense of Community

Many teachers have reported the importance of working in collaboration with other teachers during professional development implementation (Parker et al., 2015; Kyza & Nicolaidou, 2017). In a study conducted district-wide by Parker et al. (2015), teachers expressed the need for a cohort to feel a sense of community as they approached a new educational strategy. Collaboration, whether through a cohort or through working together during a workshop, encourages teachers to provide feedback and insight from their colleagues, resulting in more self-efficacy with the material covered. Teachers have expressed collaboration to be a critical factor in professional development, and it is associated with a positive effect in subsequent student results following their teacher's involvement in this collaborative practice (Kyza & Nicolaidou, 2017).

Reflective Practice

Consistent throughout the literature on teacher professional development is the nod to reflective practices. Reflection allows participants to reflect on what they have digested from professional development throughout the entire professional development implementation (Chitanana, 2012), whether it be a short workshop or a year-long course. This practice is noted across all forms of professional development and learning studies and has revealed itself to an effective method across teacher professional development (Aldahmash et al., 2019).

Explicit Objectives

Among the many methods and strategies used in professional development, several consistently surface in the literature. Explicit goals and objectives for teachers are essential for various reasons but have shown to increase the likelihood of successful professional development (Mundry & Loucks-Horsely, 1999). These goals could differ, depending on whether the PD focuses on content or pedagogical approaches.

Content Knowledge

When professional development centers around content knowledge, teachers gain new information on the content relayed to their students. PD opportunities focused on content knowledge have shown positive effects on students' learning (Kennedy, 1998), allowing teachers to interact with the material they will deliver to their students. As the education system evolves, teachers need to build upon their content knowledge (Dikilitas, 2016) with new content addressed in state-wide and nation-wide standards.

Pedagogy

While many teachers express a need for PD focused on content knowledge, others express a demand for pedagogical strategies to deliver the content. Teachers have expressed the need for experience with pedagogical strategies in professional development workshops and their classrooms (Parker et al., 2015). By allowing teachers the opportunity to apply new pedagogical strategies in their classrooms, teachers have the opportunity to receive feedback and adjust their implementation accordingly (Mundry & Loucks-Horsley, 1999).

Professional Development in STEM Education

As STEM education continues to grow in the education system, demand before the COVID-19 pandemic was increasing for teacher professional development in various STEM education methods. To feel adequately equipped to approach STEM education, many teachers were seeking professional development in the content areas of which they are least familiar. PD in engineering education has produced positive results in student achievement (Guzey et al., 2017). Pre-service teachers also sought out opportunities for exposure to STEM education. Go & Kang (2015) found that science courses in higher education positively influence pre-service teachers' self-efficacy with science content.

Several strategies are employed to provide teachers with the appropriate STEM content and pedagogy through professional development. Modeling produces positive results with teachers' exposure to STEM (Parker et al., 2015). Teachers immersed in design-based learning during PD workshops have also reported success with STEM content (Mishra & Koehler, 2006). By modeling the pedagogical strategies for teachers participating in the PD, they gain both the content and the pedagogy by observing how it can be applied in a classroom setting and experience the activities for themselves.

There have been many successful professional development opportunities in online, face-to-face, or blended learning formats when immersing teachers in professional development for STEM education, and for teachers who wish to develop knowledge on Integrative STEM Education (Havice et al., 2018; Rasmussen & Byrd, 2016). Integrative STEM education, or the intentional integration of STEM disciplines through technology/engineering design-based learning (Sanders, 2013), allows teachers to provide their students with authentic STEM content experiences. Havice et al. (2018) found that elementary teachers immersed in I-STEM professional development were not only showing positive results from I-STEM PD but were also eager to experience more.

Blended Learning

The structure of teacher professional development can take many forms. Online professional development allows teachers to participate synchronously in real-time or asynchronously on their own from any location of their choosing. For example, the Integrative STEM Education program at Virginia Tech allows teachers to participate synchronously, with an additional option for face-to-face meetings, allowing teachers to interact with one another in discussion while learning new content and pedagogy (Wells, 2013). There are benefits to synchronous delivery online, but a combination of both synchronous and asynchronous delivery can also be beneficial (Rasmussen & Byrd, 2016). With any delivery method, passive content dissemination should be avoided (Bozkus & Bayrak, 2019) but can be eliminated through discussion between teachers, virtually or in-person.

An alternative to strictly face-to-face or online professional development is blended learning professional development (Head et al., 2002). Blended learning, also known as hybrid learning or multimodal instruction or learning (Irvine, 2020), consists of a combination of instructional settings or delivery methods (Stein & Graham, 2020). Varkonyi (2017) believes blended learning will become the traditional form of professional development and online educational delivery in the future. The blended learning model maintains online learning convenience while still allowing face-to-face opportunities to interact with the material and encourage face-to-face discussion (Snart, 2010). The Valley Stream Union Free School District 13 (2018) implemented this professional development method, allowing teachers to pick and choose the blended learning courses they wish to participate in within the school. By utilizing the convenience of online learning while still allowing face-to-face interaction, the blended learning model provides an alternative to limiting courses to one delivery method.

Synthesis

With the current emphasis on STEM in our education system, teachers are looking for new resources and opportunities to use in their classrooms to reinforce these disciplines and the 21st-century skills developed when integrating them. Through the necessity of hands-on approaches for adult learners (Bufkin & Bryde, 1996), online professional development must be administered in a manner to allow for both reflection and interaction. Blended learning professional development, or the use of multiple PD methods, can be used to facilitate a combination between face-to-face hands-on learning and synchronous or asynchronous web-based delivery.

Elementary Design-based Learning

Exposing students to STEM education in their elementary years is crucial to building a foundation for a STEM literate future (Nadelson et al., 2013). To reach students with educational opportunities that will build upon their STEM literacy, elementary teachers must attend professional development for both content and pedagogy in STEM implementation (Nadelson et al., 2013; Estapa & Tank, 2017; Cajas, 2001). While design-based learning is but one approach to STEM education, elementary teachers need opportunities to view the scope of design-based learning through an interactive and immersive professional development opportunity. For teachers to properly equip their 21st-century students for their futures, STEM professional development is imperative for elementary school teachers (Nadelson et al., 2013).

Teacher Self-efficacy and Proficiency in STEM

Self-efficacy, or one's belief in their ability to be proficient at a task (Bandura, 1977), is key to proficiency. For teachers specifically, their self-efficacy in their instructional delivery is key to ensuring their proficient in teaching and ultimately ensuring students' achievement (Barni et al., 2019). Elementary teachers have reported low levels of self-efficacy with STEM education in particular when lacking content knowledge on STEM disciplines and Integrative STEM education (Wells, 2017). To address the gap in teacher experience in pedagogical and content knowledge with STEM education and engineering design (Guzey et al., 2017), high-quality professional development opportunities need to be available for teachers to build upon their STEM education toolkit and self-efficacy. Due to the recent shift in the education system to a virtual environment, these offerings must also be transferrable to online delivery. To do this, teachers must first feel that professional development is worth their time. Teacher buy-in is essential to successful professional development opportunities (Archibald et al., 2011).

Following the professional development, evaluation in short-term and long-term results in teacher self-efficacy and ability to implement the material is crucial to assessing the professional development (Archibald et al., 2011; Veziroglu-Celik & Acar, 2018) and the teachers' proficiency in STEM education strategies. Reoccurring follow-up or observations for the period following the PD opportunity allows insight into whether or not it reached the students and was taught correctly (Veziroglu-Celik & Acar, 2018). Follow-up can consist of teacher collaboration, evaluation, or feedback to assist in continued support with the material (Archibald et al., 2011). Havice et al. (2018) found success in teacher follow-up with both short-term and long-term evaluation, in addition to discovering that teachers who participated in the program were eager to gain more experiences with Integrative STEM education. Tools are also available to assess teacher proficiency with specific content covered in the educator workshop. Capobianco et al. (2017) developed the Engineering Design-based Science Teaching Observation Protocol (EDSTOP), a tool used to evaluate teachers' proficiency in teaching engineering design-based practices. If appropriately implemented, teacher professional development can increase teacher proficiency in STEM education (Archibald et al., 2011; Havice et al., 2018; Capobianco et al., 2017).

After exposure to teaching STEM education methods, many teachers reported positive experiences with STEM professional development (Erdogan & Ciftci, 2017; Bleicher, 2007; Parker et al., 2015; Havice et al., 2018). In a two-day professional development institute with elementary teachers, Havice et al. (2018) found teachers wanted to experience more Integrative STEM professional development and were willing to seek it out after experiencing an increase in their self-efficacy with I-STEM practices following their experience in the professional development course. Pre-service teachers have also shown positive self-efficacy with STEM content after getting hands-on experiences with various practices in broader STEM education (Erdogan & Ciftci, 2017; Bleicher, 2007). Despite the lack of STEM knowledge for many elementary teachers, research has shown STEM professional development to be an effective way of mitigating their self-efficacy gaps. Wells (2017) reported elementary teachers lacking specific STEM discipline content knowledge were equally as likely to meet the cognitive demands needed for design-based learning as those who studied specific STEM disciplines with the appropriate training (Wells, 2017).

Professional Development in Design-based Learning

The need for elementary teacher professional development with design-based learning through Integrative STEM education is driven by the research revealing elementary in-service and pre-service teachers' lack in self-efficacy with STEM education (Havice et al., 2018; Bleicher, 2007; Wells, 2010). In pre-service teacher programs, elementary teachers are rarely given sufficient content knowledge for each of the STEM disciplines and rarely exposed to the various methods of disseminating STEM education. Wells (2010) reported that science and technology pre-service programs seldom exposed teachers to proper training in design-based learning and integrative approaches. As elementary teachers are expected to teach general knowledge in fundamental science concepts (Wells, 2010), they are the least likely to experience professional development or pre-service teacher experience with design-based learning and the various other STEM education methods.

The overarching goal behind PD in design-based learning is to transfer opportunities in STEM education to students so they can build upon their STEM literacy and 21st-century skills required from the future workforce (Honey et al., 2014). The presence of design-based learning was steadily increasing before the COVID-19 pandemic, raising the demand for a variety of professional development options in design-based learning across K-12 education (Wells, 2010). With this approach to Integrative STEM education, teachers need training in facilitating 'how' questions versus the traditional 'why' or 'what' questions (Fortus et al., 2004). Another critical component to professional development in design-based learning includes teacher self-efficacy in cross-curricular STEM content (Sanders, 2008).

Many studies have found success in administering teacher professional development with design-based learning and Integrative STEM Education using modeling, hands-on activities and providing teacher support consistently throughout (Bleicher, 2007; Capobianco et al., 2017; Guzey et al., 2017; Haciomeroglu, 2018; Honey et al., 2014; Parker et al., 2015; Wells, 2013). Access to the curriculum (Wu & Albion, 2019) and the opportunity to participate in a design-based learning activity (Wells, 2013) are beneficial factors to teacher self-efficacy after participating in PD. Engineering is a discipline that teachers are less familiar with, resulting in teachers' requests to focus on pedagogical strategies in engineering education (Guzey et al., 2017). A balance between content knowledge and pedagogical strategies is critical in giving teachers' an immersive experience that will properly train them in implementing design-based learning in their classrooms.

Support throughout and following teacher professional development helps teachers' self-efficacy with new practices (Parker et al., 2015; Wu & Albion, 2019). Support can take the form of consistent communication between the participants and the PD facilitator or communication through discussion amongst the participants. Wells (2013) stressed the importance of promoting discussion amongst those involved in professional development. Bleicher (2007) also noted the importance of guidance by the facilitator to ensure teachers with minimal experience in the strategies can implement the practice in their classrooms. By providing teachers with support amongst the participants and the facilitator, the teachers are more likely to succeed when implementing design-based learning in their classrooms.

The ultimate goal of teacher professional development in Integrative STEM is to prepare teachers to teach robust design-based learning units with confidence, allowing their students the chance to develop the 21st-century skills needed for their future. Students need preparation for a future workforce heavy in STEM-related fields (Honey et al., 2014). By preparing elementary teachers in design-based learning despite the current virtual environment with evidence-based best practices, we are creating change agents to disperse this integrative strategy to disseminate STEM content and 21st-century skills (Wells, 2013).

Further Research

In a review of the literature on STEM education, Integrative STEM education, and design-based learning, it is evident there is a need for additional research on these practices concerning teacher professional development. While research in science education implementation increases (Wells, 2010), there are few studies in integration across STEM disciplines (Honey et al., 2014), and even fewer studies are targeting how to implement Integrative STEM successfully (Havice et al., 2018). Further research is also needed on how the students are impacted due to teacher professional development (Kyza & Nicolaidou, 2017). Research in professional development with design-based learning for teachers across all grade levels (Sanders, 2010), specifically elementary teachers, is needed. Most pressing above all of these gaps in the research is the current emerging gap in research for whether or not teachers feel equipped to implement design-based learning in a virtual environment and what professional development, support or additional resources can do to help them accomplish this new task.

Synthesis

Design-based learning is an Integrative STEM pedagogical practice, allowing students to apply content knowledge in the STEM disciplines in an authentic setting (Wells, 2010). Elementary teachers typically trained in fundamental science pedagogy and content need further guidance on administering design-based learning in their classrooms (Bleicher, 2007; Wells, 2010). With the elementary age-range being a crucial period in a student's STEM perception (Nadelson et al., 2013), professional development in design-based learning is imperative for teachers interested in utilizing this method in disseminating STEM experiences to their students.

Distance and Online Education

Demand for Online Education

As the education system evolves, so does the method of delivery across educational fields. Online or distance education for students has become increasingly popular and mandatory due to the COVID-19 pandemic (Ferdig et al., 2020). Online professional development (PD) has also been leveraged during the unprecedented global pandemic (Hartshorne et al., 2020). Both online education and online teacher professional development have been leveraged for many years (Renninger et al., 2011), with the evolution of methods in online delivery. Even before the pandemic, many teachers appreciated the convenience factor in online PD, allowing them to participate from any location with connectivity (Collins & Liang, 2015), and in some cases allowing them to participate whenever it is most convenient with asynchronous delivery. Crepon (2014) also found online learning or ‘e-learning’ to eliminate costly materials and time limitations.

Online education has been present for over a decade, yet the demand continues to increase rapidly, even before the shift to virtual education environments to accommodate the COVID-19 global pandemic (Klemm et al., 2002; Zashchitina et al., 2018). Mackey et al. (2012) conducted a case study in New Zealand to highlight the use of blended learning to address limitations for strictly in-person instruction due to a lack of infrastructure caused by earthquakes. Beatty (2019) also developed the Hybrid-Flexible (HyFlex) course design using an approach to blended learning to accommodate students in crises, unable to attend physical classes on a regular basis, or for schools unable to provide proper infrastructure to meet the needs of a growing student body. Higher education institutions have also been utilizing this educational delivery method, increasing demand from students for courses offered online (Snart, 2010). Regarding teacher professional development, teachers have reported the benefits of convenience when participating in online education (Parsons et al., 2019) and the benefits of accessibility for those who are disabled or in remote geographic locations (Kusmawan, 2015). These factors contribute to the literature on the benefit of this method and contribute to the increasing demand for online course offerings in higher education and professional development opportunities for in-service teachers. As the education system evolves and the demand for virtual connections increases, the researched benefits, and challenges of online teacher professional development will become increasingly important to support this increase in demand.

With an increase in the demand for online and blended learning (Snart, 2010; Fullan & Langworthy, 2014), there needs to be an increase in research studies analyzing these methods for learning and professional development in the field of elementary STEM education and teacher professional development. Educators involved in online professional development have listed both benefits and challenges to this delivery method (Collins & Liang, 2015; Dede et al., 2005). Past research also highlights the impacts and progress of online and blended learning across K-12 education (Kennedy & Ferdig, 2018).

Trends in Online Teacher Professional Development

When introducing technology into the equation with teacher professional development, we must go beyond merely introducing it to assessing the components needed for delivery (Mishra & Koehler, 2006). If administered correctly, web-based professional development can help eliminate barriers found by teachers with limited time, those with disabilities (Kusmawan, 2015), or those located in underserved areas (Brasili & Allen, 2019). Among studies in web-based educational delivery, two key factors arise in whether online delivery is successful. Virtual support, or a sense of community, and course design are two components that have surfaced as critical elements in online course design and professional development delivery.

Virtual Support

One trend emerging as a best practice in web-based professional development is the presence of interaction between the course facilitator and the participants, and interaction among the participants through means of discussion (Chitanana, 2012; Owen et al., 2018; Prestridge, 2010). Heavily rooted in the constructivist approach, online learning enhances teachers' opportunities despite the virtual nature of the course (Chitanana, 2012; Kusmawan, 2015). Bond and Lockee (2014) emphasized the importance of developing a community of practice within an online environment between colleagues to provide additional support. When virtual professional development replaces face-to-face PD, the interaction between participants is maintained to facilitate discussion and growth (Owen et al., 2018). Prestridge (2010) found teachers' sense of community within an online environment to be a critical factor in the educators' involvement.

Course Design

Intentional course design that addresses the online environment is another best practice evident in the literature (Brasili & Allen, 2019; Chitanana, 2012; Head et al., 2002; Koehler & Mishra, 2005; Lockee et al., 1999). Before designing a course, one must first choose or become familiar with the web-based platform they will be administering the professional development on (Brasili & Allen, 2019; Holden & Westfall, 2007). Once the platform is selected, intentional instructional methods must be designed to fit best the online environment (Head et al., 2002) while still maintaining the course's rigor (Lockee et al., 1999). Alvarez et al. (2009) describe teachers' various roles in courses, defining the design role as a critical component to web-based education. Head et al. (2002) also emphasize that web-based features must also be carefully selected to meet the course's needs appropriately. When looking at course design, it is essential to recognize that this not only applies to synchronous web-based professional development but also PD utilizing asynchronous delivery in a blended learning format (Holden & Westfall, 2007). Professional development meshing both synchronous and asynchronous interaction has produced positive results in a study by Rasmussen and Byrd (2016). The course design must be intentional, regardless of the level of interaction among participants involved.

Online Teacher Professional Development Studies

Online professional development is a convenient and beneficial way to disseminate pedagogical knowledge to teachers (Renninger et al., 2011), especially in the current environment limiting face-to-face interaction due to the COVID-19 pandemic. The importance of building an online professional development course with embedded support has been studied for several decades. Kusmawan (2017) conducted a study on microteaching through video-based delivery, reporting that teachers found the online discussion forum to be the most beneficial component. Overall, the teachers reported the online environment as a positive experience, primarily attributed to the discussion and video-based lessons. Kusmawan (2013) found video-recorded lessons, in particular, to be beneficial for teachers. Parsons et al. (2019) found teachers to be very appreciative of the convenience factor in online professional development, allowing access to the material anytime, from anywhere. In looking at course design, Koehler & Mishra (2005) conducted a study on online course development, resulting in the teachers' belief that online courses require more time, commitment, and different course designs. Gibson (2018) also found that online courses required various delivery methods depending upon the nature of the professional development and cultural awareness for diversity across the potential international range of participants.

On an international scale, Rienties et al. (2013) discuss the need for further research when looking at teacher professional development delivered virtually. Their research found teacher scores to be higher than before the online professional development delivered for this study but felt this could be explored further on an international stage. Lockee et al. (1999) contribute to this notion by emphasizing the need for longitudinal studies when looking at online delivery. Ideally, web-based professional development would be delivered with longitudinal research on whether the teachers could continuously implement the pedagogical approach in subsequent years and whether it affected the students' achievement scores.

Synchronous and Asynchronous

As mentioned in the previous section overviewing professional development models, blended learning professional development has been studied for effectiveness in combining face-to-face and virtual professional development opportunities. Another version of blended learning professional development is combining synchronous and asynchronous methods of delivery. Rasmussen and Byrd (2016) conducted a study in which combining synchronous and asynchronous delivery produced positive results for teachers. By allowing teachers time to participate as a cohort and allowing time for independent activities in the web-based platform, teachers found the professional development to be beneficial and helpful in establishing continued use of the content (Rasmussen & Byrd, 2016).

Challenges in Online Professional Development

Technological Limitations

One of the reported challenges with online teacher professional development before the COVID-19 pandemic was technological barriers. Brasili and Allen (2019) conducted a study in which the participants reported difficulty with bandwidth in remote locations. Online professional development requires a stable wireless connection, which is not accessible to all. Another challenge reported under technological barriers is familiarity with technology (Brasili & Allen, 2019). Due to the many different video-conferencing platforms, some teachers may have difficulty navigating the platform to participate in professional development.

Engagement

An additional issue reported with online professional development is the potential for lack of engagement without face-to-face interaction (Bozkus & Bayrak, 2019; Collins & Liang, 2015; Renninger et al., 2011). Bozkus and Bayrak (2019) reinforce the importance of intentionally designing courses to promote engagement among participants and avoiding passive teleconferencing. The absence of face-to-face interaction presents a challenge of passive participation (Colling & Liang, 2015). The participants' engagement is mainly due to the structure and rigor of the course (Renninger et al., 2011). However, courses with too much rigor could cause information overload, which Collins and Liang (2015) have found among participants in online courses. Zhang (2018) recognizes that online professional development's success depends on the teacher's willingness to obtain knowledge, so allowing educators opportunities to engage by regulating their practice could help mitigate this issue.

Synthesis

As the demand for online teacher professional development increases, especially in light of the current restrictions for face-to-face interaction, it is imperative to identify best practices and essential elements for administering PD online and acknowledge the challenges that accompany an online learning environment. One of the consistent topics in online educational settings is the importance of discussion and continuous support. Another overarching best practice was identifying an intentional course design that best fits the participants' needs and the topics addressed in professional development. Online professional development can be a beneficial tool for teachers if designed and implemented to meet the online learner's needs effectively.

Video Observation and Feedback

Video has another significant role in education besides serving as a tool for teacher professional development. Video observations have been used in a variety of settings throughout education to assist in teacher evaluation and reflection (Cahalan, 2013; Hamilton, 2012; Hannafin et al., 2010; Kong, 2010; Kourieos, 2016; Sherin, 2004; Sherin & Van Es, 2005; Wang & Hartley, 2003) and student observation (Coppens et al., 2016). Video observation, often used in place of face-to-face observation (Sherin, 2004), allows the viewer to focus on any classroom environment element needed for the observation. This practice has remained constant with its benefits, allowing teachers to take on a reflective role as they watch themselves or their colleagues in a video for reflection. This observation method helps pre-service teachers wishing to reflect on their pedagogical knowledge (Wang & Hartley, 2003), in-service teachers, or researchers hoping to analyze different components in a classroom.

Much like online or video-based teacher professional development, video observation has a convenience factor. Observations recorded via video can be re-watched at the viewer's convenience, allowing teachers and researchers to analyze various parts of the classroom during a lesson (Cahalan, 2013; Hannafin et al., 2010). Video recordings can also be re-watched as many times as needed (Coppens et al., 2016; Sherin & Van Es, 2005). To take the video recordings a step further, researchers using this tool could also record student or teacher interviews to be re-watched and analyzed alongside the lesson (Kyza & Nicolaidou, 2017). In a broad study, researchers could use this data collection method and observation to allow for additional classrooms in the study, broadening the number of cases in the study (Wang & Hartley, 2003). With the convenience of recording classroom observations versus requiring face-to-face observation, the observer is broadening the number of variables they could study and the range of classrooms they could observe.

The most frequently cited purpose for video observation in an educational setting is for pre-service and in-service educator reflection (Cahalan, 2013; Hamilton, 2012; Hannafin et al., 2010; Kong, 2010; Kourieos, 2016; Sherin, 2004; Sherin & Van Es, 2005; Wang & Hartley, 2003). Video analysis of teaching practices allows educators to reflect on their pedagogy (Hamilton, 2012; Hannafin et al., 2010) or that of their colleagues. The convenience of video observation also allows observers to re-watch the video. Kourieos (2016) found that educators provided more in-depth feedback after watching the video recording at least two times. The convenience of video observation in an educational setting is studied by many and has revealed best implementation practices.

Evidence-Based Video Observation

Feedback and Reflection

Video observation has been used in a variety of settings to provide teachers with opportunities to reflect on their practice, in addition to opportunities in gaining feedback from others (Kong, 2010; Kourieous, 2016; Sherin, 2004). Kourieos (2016) analyzed the use of microteaching with video observation, finding that the video was beneficial to pre-service teachers' awareness of content knowledge and pedagogical practices. Also conducting a study on pre-service teachers, Kong (2010) found participants to successfully reflect on their teaching after watching the video alongside example videos and a self-reflection framework. Sherin (2004) emphasized the popularity of video as an observational tool to reflect on teaching practices and reflect on modeled teaching behaviors. This study also reverberated the positive impact of using video as a tool in teacher reflection.

Student Observation

Not only can video be used as an observational tool for reflective teacher practices, but it can also serve as a tool to observe student behavior as a result of teaching practices (Cahalan, 2013; Coppens et al., 2016; Hannafin et al., 2010; Sherin & Van Es, 2005; Wang & Hartley, 2003). Coppens et al. (2016) used video as a tool to specifically address student behavior in a laboratory and found it to be a beneficial tool for accurate observation. In a study analyzing teachers' teaching practices, Sherin and Van Es (2005) found the teachers reflecting on the video to begin shifting their attention to how the students responded. Video recordings and observation can provide a broad vantage point (Hannafin et al., 2010), so teachers and researchers can observe multiple aspects of the room each time they re-watch the video recording. To ensure these vantage points are accessible, the video camera must have a view of the students if they are in an in-person educational setting (Cahalan, 2013). Observations on student learning and behaviors are beneficial for pre-service teachers who anticipate the future audience of their teaching practices (Wang & Hartley, 2003).

Re-visiting

As mentioned before, video observation has a convenience factor in that the observers can re-watch the recorded teaching practices wherever and whenever they wish. Re-watching the video is encouraged as a best practice in order to get the most meaningful reflection. Kourieos (2016) found teachers to have more in-depth reflections upon watching the video at least twice. Video observations can be re-watched as often as needed to view the variety of vantage points (Coppens et al., 2016) or until the teaching practice and interactions among students become evident (Cahalan, 2013). The videos can also be re-watched later, as they are a permanent record of the teaching practice (Hamilton, 2012; Sherin, 2004; Sherin & Van Es, 2005) unless otherwise requested by the observed.

Teacher Perceptions of Video Observation

In a study conducted by MacKinnon et al. (2016), evaluators used the Stallings instrument to evaluate video-recorded observations of teachers displaying certain behaviors while teaching. Participants in the study reported that the video observation was more comfortable, allowing for more flexibility and a broader view (MacKinnon et al., 2016). Issues reported with face-to-face observations included difficulty in writing and observing at the same time, as well as more difficulty in coding behaviors in real-time (MacKinnon et al., 2016). This study gives insight into teacher perception of video-based observation, showing that some teachers believe this to be an effective alternative to face-to-face classroom observation.

As mentioned before, Kourieos (2016) conducted a study on video observation microteaching, which provided additional information on teachers' perceptions of this observation method. Participants within this study reported video observation followed by reflection to improve teaching practices (Kourieos, 2016). Kourieos (2016) also noted participants' reflections to be more descriptive after watching the video observation multiple times, a capability that is not achievable with real-time face-to-face classroom observation. When looking at the results of this study, in addition to the results of the MaKinnon et al. (2016) study, it is evident that video observation has the potential for value as a replacement to face-to-face classroom observations.

Challenges in Video Observation

With the benefits of video observation reported above, several studies have also highlighted the challenges of video as an observation tool. First and foremost, permission must be obtained by all involved in the video if it is used for external purposes. Bozkus and Bayrak (2019) found issues with this when they were denied permission for video recording of a classroom and interviews they wished to distribute. Sherin (2004) brings forth several issues with video as an observational tool, including the researcher's passive role, the limitations of a camera lens, and a potential lack of contextual information. When using video as an observational tool, Sherin (2004) also notes that it cannot simply replace face-to-face observation. Specific measures must be taken to make accommodations for the changes between classroom observations and observations recorded on video.

Hannafin et al. (2010) express concern in the lack of research in video observation, specifically regarding web-based instructional methods' validity and reliability. When new technologies and trends materialize, teachers must first assess the research on these new technologies before jumping to use them (Hannafin et al., 2010). Video has been used as an observational tool for many years, but we must continue to assess how to use it effectively when working with different web-based platforms and with new video technologies.

Synthesis

Video can be used for various purposes in education, whether it be as an observational tool, a tool for disseminating content knowledge, or a training tool for professional development (Varkonyi, 2017). Many benefits are reported as a result of using video as an observational tool versus face-to-face methods, but there are also challenges and obstacles one will face when selecting this observation method. When using video to perform observation, intentionality is vital in ensuring all vantage points are accessible through the video, and all appropriate permissions have been granted based upon how the video will be used. Convenience, vantage points, and the ability to re-watch an endless amount of times add to the list of benefits to this method of observation, making it a viable option when assessing whether or not a study should consist of live or virtual observation.

Introduction to Research

Teachers need more STEM education experience in order to equip the future workforce with 21st-century skills (Chalkiadaki, 2018). Integrative STEM Education through design-based learning is an approach to equipping students with the critical-thinking skills needed to prevent leaks in the increasingly important STEM pipeline (Sanders, 2008). The study outlined in this literature review will be looking specifically at 1) the effect of the COVID-19 pandemic on teacher self-efficacy with delivering design-based learning to elementary students and 2) identify resources and support teachers need to administer online delivery of design-based learning with elementary students in the current environment. These two research questions aim to contribute to the current literature in STEM education and reveal how teachers can navigate implementing design-based learning with elementary students in the current environment.

The subsequent literature review contributes to the research design outlined in this study. Evidence of approaches to research in supporting teachers with implementing design-based learning, professional development, and virtual approaches to professional development helped mold the strategies selected to best analyze the research questions in this study. Before participating in interviews to shed light on the research questions guiding this study, teachers who volunteer to participate in this study completed the Teacher Efficacy and Attitudes Toward STEM Survey (T-STEM) to show their overall self-efficacy with delivering STEM content (Friday Institute for Educational Innovation, 2012). While their responses to the survey were recorded, they were solely used to identify the self-efficacy of participants who volunteered for this study. The teachers' self-efficacy with STEM helped to recognize the type of teachers who volunteered to participate in this study.

Researcher Positionality and Bias

A key component in eliminating researcher bias in educational research is neutrality (Mallozzi, 2009). When developing a research study, the researcher must first acknowledge their place in the scope of the research by addressing any involvement or connections to the variables involved. This involvement includes acknowledging personal theories when conducting an interview (Mallozzi, 2009) or membership within a community or organization (Chitanana, 2012). Creswell (2014) iterates that vested interests in a study can increase the chances of researcher bias and suggest selecting research sites to which the researcher has no connection to or interest in seeing positive outcomes. If a connection exists, researcher positionality and researcher bias must be consistently addressed and accounted for throughout this study. To eliminate researcher bias, reflexivity or actively acknowledging one's role and predispositions to the research topic is essential in ensuring the study's validity (Johnson & Christensen, 2017; Lincoln, et al. 2011).

In designing this research study, the researcher must first distinguish their role within the study (Mallozzi, 2009). The researcher must acknowledge the influence any connection to the study will have, especially when studying a population to which they previously belonged (Chitanana, 2012). During the data collection and analysis phase, the researcher will need to practice reflexivity, or self-awareness, when interviewing or interacting with participants if they have a vested interest in the topic (Johnson & Christensen, 2017). The researcher must be explicit about their involvement with the topics addressed in the study and their involvement with the community if applicable. The researcher must also maintain neutrality when coding any responses or completing data analysis within the study (Mallozzi, 2009).

Research Paradigms

Research paradigms and their dimensions differ based upon the context and purpose behind a study. A research paradigm, or the perspective held by researchers when conducting a study, affects the research design (Johnson & Christensen, 2017), whereas the dimension or basis of these paradigms determines the nature of the paradigm (Lincoln et al., 2011). Studies conducted on STEM education and design-based learning are primarily rooted in the constructivist theory (Fortus et al., 2004; Sanders, 2008), emphasizing learning through means of inquiry. Referred to as constructionism by some, Charmaz (2008) reiterates constructionism to address the what and how of a particular occurrence. Studies conducted in online learning environments are also heavily rooted in the constructivist theory (Chitanana, 2012). Chitanana (2012) found the constructivist approach effective in online course delivery, allowing educators to learn collaboratively through a shared learning environment. Bufkin and Bryde (1996) report critical thinking and self-evaluation to be essential features in the constructivist paradigm, both of which are also critical components to design-based learning and online learning environments.

Research dimensions

When looking at research dimensions, ontology addresses the reality, epistemology addresses what we know about it, and methodology determines how we learn more about it. Lincoln et al. (2011) describe how these three dimensions apply to the research paradigms and how the research paradigms can be interwoven throughout the research. Crotty (1998) defines epistemology as the theory of knowledge surrounding a perspective, whereas the methodology is the plan of action determined in conjunction with a particular perspective to contribute to this knowledge. Throughout a study, the methods or techniques used are based upon the methodology and theoretical approach to a study (Crotty, 1998).

Research Problem

As mentioned early on in this literature review, the STEM pipeline in America refers to the path students take to lead to eventual STEM careers demanded of the 21st-century workforce (Ball et al., 2017). Unfortunately, this pipeline has been shown to produce several possible leaks (Allen-Ramdial & Cambell, 2014; Ball et al., 2017). Students need exposure to pedagogical strategies that allow them to build 21st-century skills (Chalkiadaki, 2018). Due to the COVID-19 pandemic, the challenge has been presented to teachers to find a way to continue to expose students to STEM in a virtual environment. STEM education continues to spread throughout education in the U.S., but reformation in the educational system requires addressing school culture, teacher capabilities, and educational policy for change to occur (Fortus et al., 2004). To achieve this, research is needed to support pedagogical approaches to STEM education and how they can be implemented in a virtual or blended learning format. This study will provide insight into how teacher capabilities can be supported to continue to provide STEM education in the current virtual and blended learning education environment.

Opportunities in STEM Education

According to Crabtree et al. (2019), the number of STEM and gifted education opportunities, often synonymous with STEM education, are unequal. Integrative STEM education offers students an opportunity to apply critical thinking skills to a design-based learning unit that utilizes two or more STEM disciplines (Sanders, 2008). Sanders (2008) stresses the importance of Integrative STEM education and ensuring students are exposed to this STEM education approach at an early age. By getting students involved with and excited about

STEM and design-based learning early, the educational system decreases the potential leaks in the hypothetical STEM pipeline. Maintaining this interest throughout the remainder of their K-12 education is essential to securing the pipeline and future STEM workforce (Sanders, 2008).

Early Exposure to STEM

STEM education experiences are necessary for young students as they enter the STEM pipeline in their K-12 education. Sanders (2009) believes the loss of interest in mathematics and science in a child's formative elementary years could contribute to the STEM pipeline'. Foltz et al. (2014) contribute to the literature on career choice, stating that the elementary years are critical to a students' career development. Ball et al. (2017) also report the start of the STEM pipeline to occur during a student's elementary years. Elementary-aged students are in the midst of their formative years where STEM education, particularly Integrative STEM education with design-based learning help to build upon their 21st century skills.

Teacher Self-Efficacy

Another research area mentioned in the previous section on teacher professional development is elementary teacher self-efficacy. Prior research on elementary teachers' self-efficacy with STEM education shows low confidence levels when teaching STEM in an integrated manner (Havice et al., 2018; Bleicher, 2007; Wells, 2010). This is influenced by elementary teachers' lack of training in STEM disciplines or their lack of exposure to Integrative STEM education and design-based learning (Wells, 2010). To get students to build upon their 21st-century skills through design-based learning, elementary teachers must have sufficient self-efficacy in implementing it with their students.

Teacher Professional Development

Keeping teachers equipped with the tools to teach STEM, specifically Integrative STEM with design-based learning is vital. Teachers need experience with STEM education in order to secure the STEM pipeline for students. Teachers also need more experience and training in Integrative STEM Education (Havice et al., 2018). Wells (2017) found that elementary teachers can implement design-based learning when informed of the practice despite their lack of initial training in all four STEM disciplines. To reach students at a young age, we must first train the teachers who should be equipped with the tools to implement Integrative STEM into their classrooms, even if they are in a virtual or blended learning format.

Synthesis

Undoubtedly, further research is needed in many areas concerning STEM education. Research is needed regarding the development of 21st-century skills in elementary-aged students (Chalkiadaki, 2018), and further research and instrumentation are needed to evaluate early elementary-aged students' career development (Tyler-Wood et al., 2010). Regarding teacher professional development in STEM education, only a handful of studies look at elementary teacher self-efficacy with STEM content (Havice et al., 2018; Bleicher, 2007; Wells, 2010). We must continue research in these areas to ensure we are supplying teachers with pedagogy they are comfortable with and capable of implementing with their elementary students. Developing a study to analyze teacher self-efficacy with design-based learning as an approach to Integrative STEM Education in light of the limitations set forth by the COVID-19 pandemic will collect a snapshot of what teachers are feeling and experiencing when trying to get this instructional strategy to their elementary students.

Chapter 3: Methodology

Research Questions

To address the need for STEM education at an elementary level, this study will analyze the evolution of teacher self-efficacy in design-based learning for elementary teachers due to limitations presented by the COVID-19 pandemic using Quick Response Research (QRR) (Mackey et al., 2012). By using QRR, the researcher was able to gain perspectives from elementary teachers in a timely manner to provide education stakeholders with information on what is needed to assist elementary educators promptly. The research questions guiding this study are:

1. What is the effect of the COVID-19 pandemic on teacher self-efficacy with delivering design-based learning to elementary students?
2. What resources and support do teachers need to administer online or blended learning delivery of design-based learning with elementary students in the current environment?

This study will follow a qualitative research design, seeking insight on teachers' self-efficacy in design-based learning after shifting to virtual and blended learning environments that limit hands-on activities. Interviews were administered with four STEM teachers familiar with design-based learning to identify their evolving comfort in administering design-based learning units with their elementary students. Transcripts collected from the interviews were analyzed for elements impacting teacher self-efficacy due to the virtual format for Integrative STEM education through design-based learning.

Methodology

Research Paradigm

The subsequent study will approach design-based learning and teacher self-efficacy in implementing this instructional strategy for Integrative STEM education in a virtual environment using a constructivist lens. Design-based learning through Integrative STEM Education offers students the ability to apply the content they are learning through technology and engineering-focused design challenges. "Integrative STEM education refers to the technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts and practices of technology and/or engineering education" (Sanders & Wells, 2010). By practicing the critical thinking skills exercised in design-based learning, students are more prepared for the higher-order thinking demanded in today's standardized assessments (Doppelt et al., 2008).

Design-based learning is a pedagogical approach rooted in inquiry (Kolodner et al., 1998); therefore, the constructivist research paradigm is most applicable. The study's methodology explored in this dissertation will use qualitative research to gain knowledge on the effect of the COVID-19 pandemic on elementary teacher self-efficacy with delivering design-based learning and what resources or support elementary teachers need to use design-based learning in virtual or blended learning formats. From an ontological dimension, this study will address the current education system regarding teacher self-efficacy with design-based learning in virtual and blended learning environments, based upon findings from elementary teacher self-efficacy with design-based learning.

Emerging themes from the interviews conducted for this research will illuminate the factors contributing to any change in teacher self-efficacy due to the COVID-19 education limitations. Design-based learning, a traditionally hands-on approach to Integrative STEM education, is an instructional strategy that may have been impacted by the limitation on in-person academics. This study's methodology is designed to provide research on elementary teacher self-efficacy in using design-based learning with these limitations, an area of research that is currently unchartered.

Qualitative Design

This study will use qualitative research through phenomenology to reveal the roots of any change in teacher self-efficacy through interviews with elementary teachers. Phenomenological studies aim to identify a phenomenon, and why it is occurring (Creswell, 2014). For this study, the researcher is analyzing change in elementary teachers' self-efficacy due to the shift to virtual and blended learning environments caused by the COVID-19 pandemic, and why the change is occurring. Both research questions will qualitatively address teacher self-efficacy in design-based learning from different angles. The first research question identifies the effect of the COVID-19 pandemic on teacher self-efficacy through interview questions designed to guide the participants through their evolving self-efficacy and what may have contributed to any changes. The second research question asks the participants to share what they feel may be beneficial in terms of support and resources to implement design-based learning in a virtual or blended learning format.

In addition to participating in interviews, all teachers who volunteered for this study completed the Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey (Friday Institute for Educational Innovation, 2012). This survey did not contribute to data analysis for either research question but was instead used as descriptive statistics to provide additional information on the self-efficacy in STEM education of the elementary STEM teachers who volunteered for this study. The T-STEM Survey consists of 83 Likert scale items on teaching STEM education across K-12 education levels. While participants did complete this quantitative survey measure, results were not used to coincide with the qualitative interview analysis to address either research questions' findings.

Role of Researcher

The researcher played an active role in this study as they worked to recruit voluntary participants, conducted all participant interviews, and coded the subsequent transcriptions from the interviews. After obtaining permission from Virginia Tech's Institutional Review Board (IRB) to proceed with the study, the researcher sought out elementary teachers to participate in the study using the methods described later in this manuscript. After participants were identified, the researcher responded with IRB-approved language to prompt the participants to complete the necessary steps to finish the T-STEM survey and set up an interview. During the interviews, the researcher and the participant were the only people virtually present while the interview was recorded. Following all interviews and their transcription, the researcher developed the codebook and coded the transcriptions for emerging themes. Throughout these phases of the study, the researcher practiced reflexivity, or self-awareness, when contacting and interviewing participants described in a subsequent section (Johnson & Christensen, 2017). The researcher also maintained neutrality when coding teacher responses to the interviews conducted within this study (Mallozzi, 2009).

Setting

Due to the COVID-19 pandemic and participants' locations across the nation, all participant interaction took place in a virtual format. Initial interaction and interview coordination with participants took place through e-mail. Participants were prompted to agree to participate in this study and complete the T-STEM survey through Qualtrics, a survey tool approved by Virginia Tech. All interviews took place through Zoom, a virtual platform approved by Virginia Tech. To protect all participants' confidentiality during their interview, the interviews were only audio-recorded using a Sony Mono Digital Recorder. After recording, the audio recordings were transcribed through Rev, a transcription service approved by Virginia Tech, and housed on the researcher's secured laptop. No additional interactions took place between participants or the data beyond the virtual platforms and tools described.

Participants

When identifying teachers needed for this study, several factors were taken into account. First and foremost, the population was identified (Creswell, 2014). The population for this study is elementary teachers teaching STEM content. The selection process for sampling within the population is imperative to any study (Creswell, 2014). For this study and the additional pressures on teachers in the evolving education environment due to the COVID-19 pandemic, a purposeful sample was required. The study sample included four elementary STEM specialty teachers with varying levels of years teaching STEM education. The sample consisted of teachers who volunteered to participate in this study based on their eligibility as an elementary teacher teaching STEM content, workload, and ability to participate. The sample included one teacher who taught in a suburban school district and three teachers who taught in rural school districts.

Several means of recruitment to find elementary STEM teachers willing to volunteer to participate in this study were considered to obtain the sample. After initially obtaining permission and targeting participants in one design-based learning professional development webinar with no response, the researcher found obtaining voluntary elementary teacher participants a limitation of this study. Acknowledging this as a limitation, the researcher sought out additional platforms for participant recruitment. Recruitment language approved by the Virginia Tech IRB was shared in social media forums specifically formed for STEM teachers and shared among the researcher's networks in elementary STEM education. Four teachers outside of the researcher's immediate network volunteered to participate in this study.

Kennedy (1998) cautions using teachers who are willing to volunteer for a study, as they are more inclined to adopt the ideals within a study. As previously stated, all teachers in this study are STEM teachers and completed the Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey (Friday Institute for Educational Innovation, 2012) before participating in their interview. This tool was used as descriptive statistics to identify participants' overall self-efficacy in teaching STEM content and design-based learning to shed light on their experience level as an elementary teacher teaching STEM content. The survey consists of 83 total Likert scale items in Science and Math Teaching Efficacy and Beliefs, Science and Math Teaching Outcome Expectancy, Student Technology Use, Elementary STEM Instruction, 21st Century Learning Attitudes, Teacher Leadership Attitudes, and STEM Career Awareness. As expected, all four participants who teach STEM at an elementary level reported an overall high self-efficacy with the Likert scale items regarding Efficacy and Beliefs and Elementary STEM Instruction in the survey tool and are therefore on a very similar level of self-efficacy when analyzing interview responses. Due to this finding, the researcher did not need to use the T-STEM survey results to coincide with interview responses based on varying levels of self-efficacy in teaching STEM content.

Data Collection

Following recruitment for participants, the four elementary STEM teachers received instructions for completing the T-STEM survey and arranging a one-hour time slot most convenient for the interview schedule. T-STEM data was recorded and stored on a secure laptop. For the interviews, all four participants promptly attended during their pre-arranged interview time slot and were guided through the semi-structured interview protocol listed in Appendix A. For confidentiality purposes, the participants were identified using pseudonyms with the key only accessible by the researcher. After the interview, the researcher submitted the interview recordings stored on a Sony Mono Digital Recorder to Rev, a subscription service approved by Virginia Tech. Once all four interviews were completed and transcribed, the researcher proceeded with data analysis.

Interviews

By analyzing both research questions through a phenomenological approach, interviews were determined as the best path to gaining fruitful insight on teachers' self-efficacy in the current environment. The interviews were conducted at the time agreed upon by the researcher and each of the four participants. Each participant provided one hour most convenient for them to accommodate their busy schedules, but the interviews were not limited to one hour if they were willing and able to continue the discussion beyond that time allotment. As expected, the interview times varied, and each lasted between 30-minutes to one-hour based on discussion and the participants' varying responses.

Eight pre-determined interview questions addressed both research questions to provide an in-depth analysis of the teachers' self-efficacy, in addition to what they need to feel supported in delivering virtual design-based learning. The interviews followed a semi-structured interview protocol listed in Appendix A with pre-determined questions for both research questions that were carefully crafted to evoke robust responses and allowed for open-ended discussion. Six questions guided the participants through their evolving self-efficacy to address Research Question 1, and two questions asked participants their input to address Research Question 2. All interviews were conducted through Zoom and recorded on a Sony Mono Digital Voice Recorder to ensure confidentiality. Each participant received a pseudonym for the subsequent transcription attached to their T-STEM survey results to ensure confidentiality.

Data Analysis

This study requires a qualitative analysis, seeking an in-depth understanding of teachers' self-efficacy and needs regarding delivering virtual design-based learning with elementary students. Data analysis was required for each participants' response to the T-STEM survey to determine the varying levels of self-efficacy, in addition to data analysis of the interviews that occurred with each participant. The researcher analyzed transcripts collected from the interviews using a qualitative codebook for evidence of effects on teacher self-efficacy with this instructional strategy now needing virtual implementation, themes surrounding what may have caused any change in their self-efficacy, and what resources and support they need to increase their self-efficacy in this instructional strategy intended for in-person delivery.

Following the teacher interviews' conclusion, the researcher used the university approved transcription service Rev for transcription. Prior to developing a codebook, the researcher read each transcription multiple times to pull out potential themes for coding. The researcher chose to develop the qualitative codebook and perform the coding to stay rooted in the research and to immerse themselves in the data to help find the common emerging themes. After identifying all possible themes, the researcher proceeded with developing the codebook to identify the prevalence of each theme across the interviews. Based upon the recommendations set forth by Creswell (2014), the codebook for this study developed by the researcher included the codes and their labels, both a brief and full description of each code, descriptions on when the code is appropriate to use, and an example of the code from the interviews themselves. The researcher developed this qualitative codebook in a Microsoft Excel spreadsheet, and used it as they combed through each interview multiple times to pull out all identified themes through coding. Once the coding was complete, the researcher analyzed the coding results for the most common emerging themes among the participant responses (Creswell, 2014). The emerging themes from interview responses are discussed in detail in the results of this study.

Trustworthiness

The five components necessary to ensure the trustworthiness of this qualitative study are outlined below (Lincoln & Guba, 1985).

Credibility

This study will aim to accurately reveal the effect of the shift to a virtual education environment on the participants' self-efficacy using design-based learning with elementary students and identify what resources and support the participants need to facilitate design-based learning with elementary students in the current environment. Lincoln & Guba (1985) describe trustworthiness in qualitative research as accounting for credibility, transferability, dependability, confirmability, and reflexivity. Data triangulation was initially intended for this study, as the researcher was recruiting participants and aiming to get elementary teachers with varying levels of self-efficacy with STEM to use compared to their interview responses. Despite using multiple means for recruitment over a sustained period, the researcher experienced challenges with getting volunteers for this study. As a result, the participants who volunteered for this study coincidentally reported similar self-efficacy levels on the T-STEM survey. This finding will be addressed again in the Limitations and Future Research section of this study.

Transferability

By acknowledging all aspects of this study through thick descriptions of the setting, participants' self-efficacy with STEM content and emerging themes, the researcher ensured the potential for this study's transferability (Creswell & Miller, 2000; Korstjens & Moser, 2018). In the following Results section, the researcher outlines the emerging themes from the four interviews conducted for this study, confirming the results' saturation due to their presence in nearly all interview responses.

Dependability

Lincoln and Guba (1985) refer to dependability as evidence of consistency (Korstjens & Moser, 2018). To ensure consistency during the data analysis phase, the researcher developed a qualitative codebook based upon the transcriptions of all four interviews. Using this qualitative codebook, the researcher went back through the transcriptions to record evidence of the themes identified in the codebook. This process ensured the dependability of the results by removing any evidence of the researcher's own bias or thoughts on the transcriptions' content. The researcher also outlined the phases of this study in detail in the subsequent Procedures section and strictly followed these phases to ensure proper protocol was maintained and conducted consistently across all participants.

Confirmability

Confirmability is a study's impartiality (Korstjens & Moser, 2018; Lincoln & Guba, 1985). As mentioned above, the researcher outlined the phases of this study to provide transparency and dependability of this study. Teacher interviews were administered in a controlled and consistent virtual environment throughout the study to prevent any inconsistencies in the interview responses. Interviews were also conducted at the time most convenient for the individual to prevent interruptions and inconveniences where possible. The research conducted in this study would greatly benefit from duplication to investigate the research questions with participants from varying levels of self-efficacy with STEM content beyond the above-average self-efficacy of participants who volunteered for this study, so confirmability is critical.

Reflexivity

To ensure the trustworthiness of this study, the researcher practiced reflexivity when interacting with the participants throughout all phases of the study. It is critical to practice reflexivity and recognize the researcher’s experiences they are bringing to the interview process in order to eliminate any potential for bias (Mallozzi, 2009). The researcher for this study is a doctoral student in Integrative STEM Education with a profession in STEM education. Acknowledging this and practicing reflexivity throughout the study as the researcher interacted with teachers during the recruitment and interview period prevented researcher bias from impairing it.

As Creswell (2014) iterated, vested interests in a study can increase the chances of researcher bias. Researcher positionality and researcher bias must be consistently addressed and accounted for throughout this study. To produce a trustworthy study, the researcher acknowledges their vested interests in education, professional development, STEM education, and design-based learning, topics all expressed in this study to eliminate potential for researcher bias. The researcher was a former elementary classroom teacher for three years and currently works in the education field, proving their continued vested interest in education as a whole and specific interest in elementary education. The researcher sought out professional development opportunities throughout their time as a classroom teacher and found value in the sessions or courses they could attend. With the current job role of an Education Coordinator for a government organization focused on STEM education, the researcher also believes strongly in STEM education benefits. Due to this vested interest in STEM education, the researcher is a doctoral student in Integrative STEM education, leading to their interest in design-based learning as an instructional strategy. Throughout the study, the researcher acknowledged their vested interests and kept them excluded from any discussion during interaction with participants before and during the interview to eliminate researcher bias. The researcher also acknowledged their interests when developing the qualitative codebook and subsequent coding to ensure their interests and opinions did not influence this study's results.

Procedures

Phase 1

The researcher identified social media forums for STEM educators and individuals in their STEM education network to post and send a message for recruitment approved by the Virginia Tech Institutional Review Board to find participants for the voluntary research opportunity. After the message was sent across various networks, the researcher monitored their email for research participants. Once the researcher received an email from an interested participant, they sent an approved follow-up email to provide additional information about the study with procedures for providing consent, completing the electronic T-STEM survey, and arranging a time for their interview.

Phase 2

Once each participant submitted their electronic Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey (Friday Institute for Educational Innovation, 2012), the researcher arranged an interview time with the participant during a one-hour time slot. All participants were sent a Google calendar invite for their allotted interview time and were provided with the link to their virtual interview.

Phase 3

The interviews were conducted at the time agreed upon by the researcher, and each of the five participants. Interview questions addressed both research questions to provide an in-depth analysis of the teachers' self-efficacy and what they need to feel supported in delivering virtual design-based learning. The interview followed a semi-structured interview protocol with predetermined questions that allowed for open-ended discussion. All interviews were conducted through Zoom and audio-recorded on a Sony Mono Digital Voice Recorder to ensure all participants' confidentiality was secure.

Phase 4

Following the teacher interviews' conclusion, the researcher used the university approved transcription service Rev for transcription. As the transcriptions were received, the researcher read them multiple times to identify potential themes for developing a qualitative codebook. Based upon the recommendations set forth by Creswell (2014), the codebook for this study must include the codes and their labels, both a brief and full description of each code, descriptions on when the code is appropriate to use, and an example of the code from the interviews themselves. The researcher developed the qualitative codebook in a Microsoft Excel spreadsheet after all interview transcriptions were complete. Using the recommendations set forth by Creswell (2014), the researcher organized the spreadsheet in columns labeled by code, label, brief description, full description, when to use, and examples. The researcher went back through each transcription and coded the text according to the codebook and pulled out all examples of each theme for analysis. Once the coding was complete, the researcher analyzed the emerging themes among the participant responses (Creswell, 2014). The emerging themes from interview responses are discussed in detail in the results of this study.

Chapter 4: Results

Following the interview transcription and coding phases, several themes materialized as prominent elements related to both research questions. The results explore these themes that surfaced for both research questions in detail and provide additional information to outline the coding process for this study including examples of quotes from the participants as they addressed these themes. Each interview provided robust insight into the participants' attempts to continue design-based learning and STEM education as a whole in their classrooms. While many responses were similar and reached saturation, many individualized elements for these themes surfaced and are included where applicable below.

Research Question 1

As stated, the first research question explores the effect of the COVID-19 pandemic on teacher self-efficacy with delivering design-based learning to elementary students. While the participants did allude to their evolving self-efficacies as they were guided through the interview questions geared toward the changing education environment, the participants mainly discussed the barriers they came across and are still enduring, and the remedies they have implemented to try to circumvent these barriers. The emerging themes for this research question included their evolving self-efficacy before, during, and currently with implementing Integrative STEM education, condensing student activities, condensing the Engineering Design Process, a lack of student access to materials, a lack of control on instructional delivery and the changing prioritization of STEM education.

Table 1

Emerging Themes in the Effect of the COVID-19 Pandemic on Teacher Self-Efficacy with Delivering Design-based Learning to Elementary Students

Theme	Description	Examples
Evolving Self-Efficacy	Evolving self-efficacy refers to the change in one's belief, or confidence, in their STEM knowledge, comfort, or ability to teach STEM. This description could reference before, during, or after the shift to a virtual learning environment.	"The twist with the remote learning, I feel is the materials. So that's where I feel my confidence goes, 'Doing good, doing good.' and then that's where I take a dip." – Sarah "Holy crap, how do we make this work? To be honest, that was my first initial question" – Mark "Currently, I think I would be in the middle. I'm comfortable with [Learning Management System]. I know how to put the content out. It's just how to make what I do in-person as, what's the word? I guess the same as virtual, you know what I mean?" - Tiffany
Condensing Activities	Condensing activities refers to any mention of taking full-length activities and condensing them or only using pieces of a larger activity or unit.	"From March to June, there was very little design other than, like, mini design challenges they could do, but there wasn't like a whole unit." – Tiffany "I could give a small chunk of what they could do in, in Tinkercad. And the same thing with Scratch." – Taylor "We're going to do a little mini section on CS First." - Mark
Condensing the Engineering Design Process	Condensing the Engineering Design Process refers to taking the full Engineering Design Process and condensing it into a shorter unit with all components, or removing some of the Engineering Design Process components and instead focusing on a subset of them.	"I'm actually through the steps of the design process now, instead of just haphazardly saying, 'Okay, in Scratch, we're going to animate a name," "I taught them some skills you use in Tinkercad, but using the poem. So we went through the whole engineering design process." – Taylor "I had a class that focused on design thinking and project-based learning and all that. I really try to, and I'm still trying to work through how that's going to look this year." – Tiffany "...a lot of coding, a lot of creation. We blended more from design-based build-it projects to more individualized creation projects." - Mark

Theme	Description	Examples
Access to Student Resources	Access to student materials refers to the lack of students' access to technology, WiFi, online resources, or physical materials previously provided in an in-person education environment.	"The hiccups that I've encountered are well, one technology. Two, materials." – Sarah "So even though they were home and they couldn't have the real Bee-Bot, they could at least practice programming the bee on a computer." – Taylor "They don't have the apps or the resources at home to do that. I have to think of something else that they can do at home." - Tiffany
Lack of Control	Lack of control refers to the inability to maintain classroom management in a virtual or blended learning environment or the inability to fully support students synchronously they were previously able to in an in-person education environment.	"That's just the hard thing for me, is that I'm not there to support, even though I know I'm not definitely just [doing] it for them, but just to be right there next to them. Encouraging is very different than being on a screen..." – Sarah "Because when they're in my classroom, I have control over what they're hearing, what they're learning and how they're interacting with each other. But in virtual, I don't Zoom with them. I don't see the kids unless they post a video in Canvas of themselves explaining. But I have no control over if they, number one, if they actually listened or watched the videos or read the lesson, you know what I mean? And then complete the challenge. I think right now it's just figuring that out. I'm confident that I can figure it out." – Tiffany "We're using Microsoft Teams as our conference calling platform and running that in concert with Google Classroom, which is what we use to house our assignments. And then potentially with a coding app. Running all three at the same time is difficult." - Mark
Prioritization	Prioritization refers to the emphasis placed on, or priority given to, STEM education in the school environment.	"...obviously language and math was our biggest focus." – Sarah "And when COVID happened, it was kind of everybody fight for themselves." – Taylor "It just wasn't a priority." – Tiffany

Evolving Self-Efficacy

The first research question's focal point, teacher self-efficacy, presented itself as an emerging theme as participants referenced their confidence in using design-based learning, Integrative STEM education, and STEM education as a whole. All participants reported significant experience and high self-efficacy in teaching STEM education prior to the COVID-19 pandemic, with almost all participants reporting being well-versed in design-based learning and Integrative STEM specifically. While all participants discussed their initially high self-efficacy in delivering STEM content, all participants also referenced the barriers, limitations and struggles they have encountered since the beginning of the education system's shift to a virtual environment due to the COVID-19 pandemic. One participant summed up the evolution of their self-efficacy by stating, "The twist with the remote learning, I feel is the materials. So that's where I feel my confidence goes, 'Doing good, doing good.' and then that's where I take a dip." Another participant referenced their ongoing struggle with self-efficacy in the virtual environment by stating, "... it's just I'm still stuck on how do you do it virtually basically. I have no problem and doubt that I can do it. It's just taking the time to figure it out and making it work." The significant number of barriers the participants referenced as factors contributing to their self-efficacy decrease are discussed in detail below.

Condensing Activities

To adjust to the virtual environment at the beginning of the shift to online learning, all participants referenced using condensed or segmented versions of full-length activities or units. While design-based learning lends itself to hearty units to fully integrate the STEM disciplines, participants referenced having to parse out the pieces of full design challenges to get something the students could do independently. One participant stated, "From March to June, there was very little design other than, like, mini design challenges they could do, but there wasn't like a whole unit." Participants also acknowledged the barriers of asynchronous learning with tackling full units. Another stated, "And we found all these resources that the kids could work on at their own pace, at their own interests and at their parents' discretion."

Condensing the Engineering Design Process

The Engineering Design Process, a key element in working through design-based learning, was referenced by each participant during interviews. One participant stated early on in their interview, “It's so hands-on based that it really handcuffs us in what we are trying to teach in that immersive collaborative purposely layout for how a STEM lesson or a design lesson should be." The struggle to shift from a hands-on approach to a virtual design-based activity was referenced, along with workarounds for ensuring students are still getting segmented experience with the Engineering Design Process despite limited interaction. The same participant shared an approach their team has taken by instead focusing on different elements of the Engineering Design Process that do not require build, but instead require initial design or brainstorming. Two participants also referenced creating units that placed an emphasis on the sharing piece of the Engineering Design Process with entrepreneurship.

Access to Student Resources

Another barrier the participants unanimously brought up was a lack of access to resources for the students. Resources participants referenced included a lack of access to technology, reliable internet connectivity, online resources or physical materials that are needed to help with build in design-based learning. One participant was able to attempt build projects through common household items by stating, “We found at home, design build-it projects. Things you can do with toilet paper rolls and toothpicks.” While many participants referenced a lack of capable internet connection for students, another found that students struggled to log in even with connectivity, stating “They don't have the apps or the resources at home to do that. I have to think of something else that they can do at home.”

Lack of Control

As a new educational environment to many, virtual classrooms presented a variety of barriers for the participants in this study. One of these barriers included the teachers’ inability to support elementary students in-person or manage what they are doing synchronously. One participant stated, “Because when they're in my classroom, I have control over what they're hearing, what they're learning and how they're interacting with each other. But in virtual, I don't Zoom with them. I don't see the kids unless they post a video in Canvas of themselves explaining. But I have no control over if they, number one, if they actually listened or watched the videos or read the lesson, you know what I mean? And then complete the challenge. I think right now it's just figuring that out. I'm confident that I can figure it out.”

Prioritization

All participants in this study taught STEM as a specialty course for elementary students, and all participants referenced a sudden shift in the priority for students to attend their regularly scheduled STEM course at the beginning of the change to virtual schooling. One participant stated, “...there wasn't an expectation for the kids to complete any specials.” The participant found this as a significant change, stating “I can say for certain last year before March, STEM was pretty high up on the list.”

Research Question 2

The second research question aims to gain insight on the resources and support teachers need to administer online or blended learning delivery of design-based learning with elementary students in a virtual or blended learning environment. The themes across interviews for this research question are outlined below and include the necessity for teacher support and networking, pulling on prior coursework materials, additional time for strategizing and access to resources for teachers.

Table 2

Emerging Themes for Resources and Support Teachers Need to Administer Online or Blended Delivery of Design-based Learning with Elementary Students in the Current Environment

Theme	Description	Examples
Teacher Support	Teacher support refers to support provided by fellow colleagues, or support provided by teachers across a network or on social media. This support includes curriculum resources, instructional strategies, or encouragement.	"Everyone's been sharing their brainstorms and their ideas of how they're making it work. And that's really, really valuable to me." – Sarah "I think access to other teachers in our IU or intermediate unit and time to network with them and see what they're doing and share ideas..." – Tiffany "The more that you can collaborate with others and bounce ideas back and forth, the more heads are better than one type deal, that has definitely helped boost our confidence that we can get through this even in challenging times." - Mark
Academia	Academia refers to the mention of college-level courses taken that helped the participants' STEM education knowledge.	"I just finished my master's in curriculum and instruction, but I took a STEM education class." – Sarah "I'm planning on using resources I got from the one class that I took." – Tiffany "I went through the STEM master's program at [College]. I leaned off a lot of knowledge that I gained from that and getting my STEM certification." - Mark
Time	Time refers to the participants' mention of needing additional time while working to digest incoming information, collaborate with teachers, adjust for the changes in education environments and plan accordingly.	"I think between networking and providing professional development and just time for teachers is the most important." – Tiffany "Any of them are teaching full-time, so for them to take the time beyond teaching full-time, some are going home to their kids who they're catching up with their work then at night. And then on top of that, trying to figure out what the heck am I going to teach next week? That's very overwhelming for people." - Mark

Theme	Description	Examples
Access to Resources	Access to resources refers to the participants' mention of lacking access to certain resources or wishing for additional resources beyond what they currently have. These resources include curricular, monetary, technological, physical access or professional development resources.	"Whereas now I kind of feel bad for asking for anything because I know it's not their top priority." - Tiffany "It's really hard to find virtual resources that are geared for elementary." – Taylor "I hope you're grasping some of the struggles because there's so many obstacles. It's financial obstacles, accessibility obstacles, overwhelming information overload obstacles." - Mark

Teacher Support

Fellow teacher support from colleagues, social media, or networking was referenced multiple times across interviews. This teacher support ranged from receiving words of encouragement to having the opportunity to sit down together and brainstorm. One participant specifically referenced how this has helped to re-boost their self-efficacy, stating, "The more that you can collaborate with others and bounce ideas back and forth, the more heads are better than one type deal, that has definitely helped boost our confidence that we can get through this even in challenging times." Another participant spoke to the power of fellow STEM teachers on social media for their brainstorming purposes, stating, "Seeing other examples of other people making it work, I think helps to inspire me."

Academia

While not prompted by the researcher in the semi-structured interview, three participants discussed pulling on their graduate courses in STEM education and specifically in Integrative STEM education. One participant was still working through applying what they learned in a master's course to the virtual education environment, stating, "I had a class that focused on design thinking and project-based learning and all that. I really try to, and I'm still trying to work through how that's going to look this year."

Time

During discussions on ideal conditions for implementing design-based learning in a virtual environment, two participants placed time to digest the current situation and strategize accordingly at the top of their list. With the urgency to switch to virtual in the spring, time was not a resource that teachers had. When talking about shifting design-based learning units to virtual units, one participant stated, "It's just taking the time to figure it out and making it work." Another participant highlighted another issue they have noticed with needing time during work hours, stating, "Any of them are teaching full-time, so for them to take the time beyond teaching full-time, some are going home to their kids who they're catching up with their work then at night. And then on top of that, trying to figure out what the heck am I going to teach next week? That's very overwhelming for people."

Access to Resources

The final theme which surfaced from the interview was access to resources for teacher. Teacher resources mentioned include instructional resources, financial support, technological support and training, physical access to resources and the building, and professional development resources. Two participants specifically referenced the difficulties in providing education as a whole to elementary students in primary ages, given the need to be literate to be able to do most design-based or coding applications on the computer. When looking at professional development specifically, one participant stated, "There's professional development out there that we can't afford." Another participant noted a lack of resources and confidence in asking for them due to shifting priorities. The participant stated, “Whereas now I kind of feel bad for asking for anything because I know it's not their top priority.”

Chapter 5: Discussion

Conclusions

This study intended to dive deeper into teacher self-efficacy with design-based learning in light of the shifting education environment and highlight teachers' needs in terms of resources and support to increase this self-efficacy. The results from this qualitative analysis reveal the realities of four teachers' changing self-efficacy with delivering design-based learning virtually by identifying the barriers they are facing, in addition to what they need in order to overcome these barriers. Themes that emerged from the interviews were present in nearly every interview, if not all, and provide insight into how the education system can support them during these unprecedented times. While the participants did acknowledge these barriers they face, they also identified ways they have personally adjusted to get to a place where design-based learning is still plausible in a virtual or blended learning environment.

When analyzing the effect of the COVID-19 pandemic on teacher self-efficacy with delivering design-based learning to elementary students, there was clear evidence across all interviews of a dip, or temporary decrease, in teacher self-efficacy that was mitigated through the teachers' ability to develop ways to integrate all or part of design-based learning in virtual or blended learning settings. References to the causes of this temporary decrease in self-efficacy in participant interviews included students' lack of access to resources from home, the teachers' lack of control of the virtual classroom environment and inability to support students in-person or real-time, and the sudden drop of prioritization for STEM education in schools. Teachers reported condensing activities and the Engineering Design Process as ways they initially approached STEM education and design-based learning, if possible, in the shift to a virtual classroom. The shift to virtual learning due to the COVID-19 pandemic affected the participants' previously high self-efficacy in implementing design-based learning through Integrative STEM education with their elementary students.

In investigating the resources and support the participants' cited needing to administer online or blended learning delivery of design-based learning with elementary students in the current environment, this study revealed several avenues that the education system can explore to support teachers in the current environment. Participants referenced continued support from fellow teachers, pulling on knowledge obtained in academic coursework, getting additional time to strategize, and an increase in access to curricular, monetary, technological, physical access, and professional development resources as key to using design-based learning as an instructional strategy through Integrative STEM with students moving forward in this altered education environment. The participants' reference to past coursework in Integrative STEM and design-based learning supports the findings from Havice et al. (2018) on the benefit of professional development with teacher self-efficacy in Integrative STEM and design-based learning specifically. The resources and support participants identified in their interviews are specific to these teachers but should be explored further by education stakeholders interested in supporting teachers during this time. Resources and support are critical when looking at how teachers can continue implementing design-based learning to ensure students are getting experience in 21st-century learning through this Integrative STEM education approach.

While a significant amount of the findings from this study revealed the participants' barriers, the participants also reference approaches they have implemented to overcome these barriers since the initial shift to a virtual environment. Supporting the claim from Tsui et al. (2020) that the education system can reinvent itself in a crisis, the participants in this study developed a way to reinvent design-based learning to accommodate their situation. Through brainstorming sessions with their colleagues and offering words of encouragement, finding ways to adapt the Engineering Design Process, identifying online resources students can access from home, and carving out time to redesign their initial plans, the teachers participating in this study have already made attempts to reimagine the traditional hands-on approach to design-based learning. The findings presented in this study provide hope for this instructional strategy and offer insight into how teachers and the education system can use design-based learning as an instructional strategy, despite the shift to virtual and blended learning environments.

Implications

Conclusions drawn from this study emphasize the importance of listening to what teachers need to deliver design-based learning with elementary students and supply them with the resources and support accordingly. From a practice standpoint, educators need access to quick and digestible activities and curriculum to implement in virtual and blended learning environments with their students. Providing teachers with a platform to share and collaborate is also essential in meeting their current needs. From a policy standpoint, schools and administrators must let teachers and pre-service teachers collaborate within their teams and across other teacher networks. Allowing teachers additional time during their schedules to communicate with one another and plan accordingly may increase their self-efficacy in implementing design-based learning despite the hands-on limitations and ultimately increase their success in delivering design-based learning in a virtual or hybrid setting (Barni et al., 2019). From a research standpoint, there are apparent gaps where practicing researchers can continue Quick Response Research (Mackey et al., 2012) to meet teachers where they are, as discussed subsequently.

As a current STEM education stakeholder, the researcher calls upon fellow STEM education stakeholders to use the information presented in this study to better serve elementary educators willing to implement design-based learning across education settings. Design-based learning contributes to student success by allowing them to develop the 21st-century skills demanded in their future. To ensure design-based learning is still implemented, the education system must meet teachers where they are and provide them with the resources and support the teachers identified in this study to set them up for success. This addresses the current limitations set forth by the COVID-19 and identifies approaches that can be used in other times of crisis where education may need to shift to blended learning or virtual settings (Mackey et al., 2012).

Limitations and Opportunities for Future Research

While this study's results shed light on the factors causing changing self-efficacy in design-based learning with elementary teachers, the researcher came across limitations in their research. The first and most evident limitation was the difficulties in finding teachers who were willing to participate in this voluntary study. Due to the current circumstances and the lack of time for teachers referenced in this study's results, the researcher found recruitment challenging despite recruiting across STEM education networks and social media groups. The researcher was able to find four participants for this study, but this does provide an opportunity for additional data collection from participants once teachers are not consumed by keeping up with the evolving education environment caused by the COVID-19 pandemic. By condensing the amount of time required, the researcher may find more teachers willing to participate in future research opportunities in the current environment. The researcher can triangulate this study with more participants by adding participants with varying levels of self-efficacy with STEM before the pandemic, as evidenced in their T-STEM survey results. This limitation provides future research potential as virtual and blended learning environments continue to be the nation's primary learning settings.

This study focuses on the current status of design-based learning in elementary settings due to the virtual and blended learning environments elicited by the global pandemic but does not limit itself to this unprecedented time in history. Virtual learning is a long-researched topic that many education settings have been leveraging for years (Renninger et al., 2011). As virtual and distance education becomes more prominent for elementary grades due to the current in-person limitations, it can become a long-term option for some. If this is the case post-pandemic, research in elementary virtual learning and Integrative STEM virtual education will be needed. An extension of this study to include elementary teachers with varying self-efficacies in STEM education or include teachers in grades 6-12 would help build upon the research needed for STEM education in a virtual setting.

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Appendix A

Semi-Structured Interview Guide

Opening Script

"Hello! As we've discussed through email, my name is Jessica Sain and I am a graduate student in Integrative STEM Education at Virginia Tech. I am very thankful that you volunteered to participate in this interview with me to shed light on what teachers need to deliver design-based learning virtually to elementary students. I am going to record this interview with your previously obtained consent for transcription using a pseudonym that has been assigned to you for complete confidentiality purposes, [say pseudonym]. Your actual name will not be used with anything you say today, so please feel free to speak honestly to ensure accurate data is collected! Do you have any questions prior to proceeding with the recording? [Answer any questions from participants]. [Push record] "Prior to presenting the first question, can you confirm you have read and received the information form for this study?" [Wait for participant response] Great! Do you have any questions? [Wait for participant response and answer any participant questions] Thank you. Do you grant consent to participate in this recorded interview? [Wait for participant response] Great! Let's begin."

Interview Questions

Research Question 1: What is the effect of the COVID-19 pandemic on teacher self-efficacy with delivering design-based learning to elementary students?

1. How comfortable, or familiar were you with implementing design-based learning in your classroom prior to teaching virtually, or in a blended learning format?
2. In the initial stages of teaching virtually, what were your thoughts and experiences with design-based learning as an instructional strategy?

3. As teaching virtually evolved, how did your feelings toward implementing design-based learning with your elementary students evolve, if at all?
4. What is your current comfort with using design-based learning as an instructional strategy with elementary students connecting through a virtual platform?
5. What resources have you used to assist with implementing design-based learning in a virtual format?
6. How has attending professional development affected your comfort with delivering design-based learning virtually?

Research Question 2: What resources and support do teachers need to administer online or blended learning delivery of design-based learning with elementary students in the current environment?

1. What resources do you need to deliver design-based learning virtually with elementary students?
2. What support do you need to deliver design-based learning virtually with elementary students?

Appendix B: Information Sheet for Participation

Information Sheet for Participation in a Research Study

Principal Investigator: Bradley Bowen
Co-Investigator: Jessica Sain
IRB# and Title of Study: #20-930 Elementary Design-based Learning

You are invited to participate in a research study. This form includes information about the study and contact information if you have any questions.

I am a graduate student at Virginia Tech, and I am conducting this research as part of my course work.

➢ WHAT SHOULD I KNOW?

If you decide to participate in this study, you will complete a brief survey and interview.

As part of the study, you will complete the subsequent Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey (Friday Institute for Educational Innovation, 2012) consisting of 83 Likert scale questions on teaching elementary STEM. Once this survey is complete, you will send Jessica Sain (jsain14@vt.edu) three one-hour time slots that align to your schedule for the interview conducted through Zoom. This interview will be recorded on a Sony Mono Digital Voice Recorder to ensure a secure transcription. The recording will be deleted once transcribed, and your name will be replaced with a pseudonym (false name) in the transcription.

The study should take approximately 30-60 minutes of your time. We do not anticipate any risks from completing this study.

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

➢ CONFIDENTIALITY

We will do our best to protect the confidentiality of the information we gather from you,

but we cannot guarantee 100% confidentiality.

Any data collected during this research study will be kept confidential by the researchers. Your interview will be audio-recorded using a digital recorder and then transcribed. The researchers will code the transcripts using a pseudonym (false name). The recordings will be uploaded to a secure password-protected computer in the researcher's office. The researchers will maintain a list that includes a key to the code. The master key and the recordings will be stored for the duration of the study and then destroyed.

➢ WHO CAN I TALK TO?

If you have any questions or concerns about the research, please feel free to contact Jessica Sain (757-871-3581, jsain14@vt.edu). You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research participant, contact the Virginia Tech HRPP Office at 540-231-3732 (irb@vt.edu).

Please print out a copy of this information sheet for your records.
If you would like to participate in this survey, click yes to begin or no to exit.

Appendix C: Follow-up Email

The following e-mail was sent to volunteers who identified interest in participating in the study:

To: (Volunteer email)

Subject Line: Follow-up for Virginia Tech STEM Education Opportunity

Good morning,

Thank you for reaching out to participate in this study. My name is Jessica Sain and I am a doctoral candidate at Virginia Tech in the Integrative STEM Education program. I am seeking participation for research in a study on teacher self-efficacy with elementary design-based learning in a virtual environment. This study aims to identify teacher self-efficacy with STEM content in virtual design-based learning and gain insight into what teachers need to feel more supported in delivering this instructional strategy virtually. The study requires a brief survey and an interview, which will accumulate to a 30-minute to one-hour time commitment at a time most convenient for you.

If you would like to proceed with participation in this study, please:

1. Read through the electronic information sheet and complete the subsequent T-STEM Survey. Both can be accessed at this link: https://virginiatech.qualtrics.com/jfe/form/SV_9YSVsaOdnk7kVPD
2. Please send me three one-hour time slots which align to your schedule for the subsequent interview that will be conducted through Zoom and recorded on a Sony Mono Digital Voice Recorder for later transcription using a pseudonym in place of your name.

If you have additional questions, please do not hesitate to reach out to me at jsain14@vt.edu. This study, IRB 19-1061, has been approved by the Virginia Tech Institutional Review Board (IRB).

I look forward to hearing from you!

Appendix D: IRB Approval Letter

VIRGINIA TECH.

Division of Scholarly Integrity and Research Compliance
Institutional Review Board
North End Center, Suite 4120 (MC 0497)
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE: November 13, 2020

TO: Bradley Bowen, Jessica Sain

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires October 29, 2024)

PROTOCOL TITLE: Elementary Design-based Learning

IRB NUMBER: **20-930**

Effective November 13, 2020, the Virginia Tech Human Research Protection Program (HRPP) determined that this protocol meets the criteria for exemption from IRB review under 45 CFR 46.104 (d) category(ies) 2(ii).

Ongoing IRB review and approval by this organization is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities impact the exempt determination, please submit an amendment to the HRPP for a determination.

This exempt determination does not apply to any collaborating institution(s). The Virginia Tech HRPP and IRB cannot provide an exemption that overrides the jurisdiction of a local IRB or other institutional mechanism for determining exemptions.

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

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Determined As: **Exempt, under 45 CFR 46.104(d) category(ies) 2(ii)**
Protocol Determination Date: **November 13, 2020**

ASSOCIATED FUNDING:

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

Invent the Future