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A Case Study Exploring How the Zero Barriers in STEM Education Professional Development Program Affects Attitudes and Confidence Toward Teaching STEM Content to Students With Disabilities

Alison Dossick

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

by

Alison Lockwood Dossick

Biology B.S., Virginia Tech, 1995

M.Ed., Marymount University 1999

Director: Dr. Elizabeth Edmondson

Research Associate Professor

School of Education

Virginia Commonwealth University

Richmond, Virginia

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Acknowledgments and Dedication

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This dissertation is dedicated to my beloved sister, Amanda McQuaid Smoot. Through her grace and love, she encouraged me to continue this adventure even while she departed on a journey of her own.

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Abstract

A CASE STUDY EXPLORING HOW THE ZERO BARRIERS IN STEM EDUCATION PROFESSIONAL DEVELOPMENT PROGRAM AFFECTS ATTITUDES AND CONFIDENCE TOWARD TEACHING STEM CONTENT TO STUDENTS WITH DISABILITIES

By Alison Lockwood Dossick, Ph. D.

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Major Director: Dr. Elizabeth Edmondson

Research Associate Professor

School of Education

This study was designed to assess how the Zero Barriers in STEM Education professional development (PD) course affected teacher attitudes and confidence in teaching science, technology, engineering, and mathematics (STEM) content to students with disabilities. A convergent mixed-methods case study analysis was used. The research questions were devised by examining answers on a pre-survey and post-survey. Documentation included a full analysis of two pre- and post-surveys, teacher implementation logs, team action plans, program evaluations, and semi-structured interviews. Barriers included time to plan and implement the outlined strategies and administrative and colleague support. This research uncovered some of the difficulties of implementing new PD in the classroom, along with the many outside factors that can affect PD outcomes. Despite these factors and the challenges of teaching during a pandemic, more positive attitudes about the Zero Barriers in STEM Education PD were found

making this model one that other professional organizations may want to follow when developing future science PD courses.

Keywords: professional development, special education, disabilities, science, STEM, Zero Barriers, case study, mixed methods, collaborative, elementary, middle school.

Vita

Alison Lockwood Dossick was born on May 16, 1974 in Denver, Colorado and is an American citizen. She graduated from Prince George High School, Prince George, Virginia in 1992. She earned her Bachelor of Science in Biology from Virginia Tech in Blacksburg Virginia in 1996. She received her Masters of Education from Marymount University in 1999 and taught in Prince William County Virginia for five years until 2004. She relocated to the Richmond Virginia area and taught in Hanover County Public Schools from 2006-2019 before attending Virginia Commonwealth University from 2019-2022.

Chapter 1: How Does the Zero Barriers in STEM Education PD Affect the Attitudes and Confidence of Teachers?

Highly effective teacher professional development (PD) is needed for the teams of educators teaching science, technology, engineering, and mathematics (STEM[1]) content to students with disabilities. Children, like all humans, have varying functional abilities that lie on a spectrum. When assessed by a trained educator, students can fall within defined categories of disabilities. The *Individuals with Disabilities Education Act* (IDEA) regulates who can be classified as having a disability and uses the following definition:

> A child with a disability means a child evaluated in accordance with §§300.304 through 300.311 as having an intellectual disability, a hearing impairment (including deafness), a speech or language impairment, a visual impairment (including blindness), a serious emotional disturbance (referred to in this part as "emotional disturbance"), an orthopedic impairment, autism, traumatic brain injury, any other health impairment, a specific learning disability, deaf-blindness, or multiple disabilities, and who, by reason thereof, needs special education and related services. (U.S. Department of Education, 2019, Sec. 300.8, Para. [a][1])

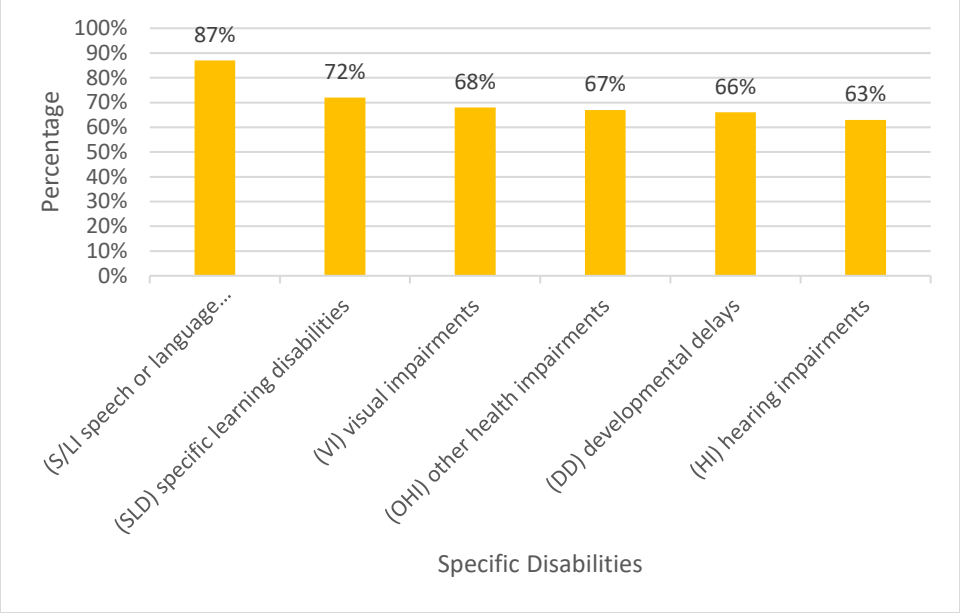
The percentage of students served under the IDEA who spend most of their school day (i.e., 80%, or more, of their time) in a general education classroom increased from 47% in 2000 to 64% in 2017 (U.S. Department of Education, 2021). As seen in Figure 1, 87% of these

[1] "STEM", an acronym for Science, Technology, Engineering, and Math, is frequently interchangeable with only science content and may apply to the combination of science and engineering in the classroom in the United States (Oleson et al., 2014). The National Science Foundation (NSF) ADVANCE Program includes the following majors in their STEM descriptions: agricultural, atmospheric, biological, computer, Earth, engineering, mathematical, physical, ocean, and all the engineering associated with these (NSF, n.d.).

students were identified as having a speech or language impairment. Seventy-two percent were labeled as having specific learning disabilities, followed by students with visual impairments (68%), other health impairments (67%), developmental delays (66%), and hearing impairments (63%; National Center of Educational Statistics [NCES], 2019). The increased number of students with varying functional abilities in general education classrooms demonstrate why general education teachers need adequate training in the appropriate tools and pedagogy to meet the needs of all learners. The SPED teacher as well as the content teacher must be able to meet the students' needs.

Figure 1

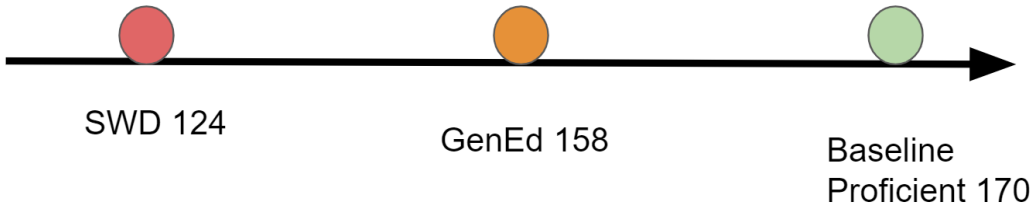
Percentage of Specific Disabilities in a General Education Setting by Category



Significant academic disparities in STEM achievement have been found between students with and without disabilities, hindering the ability of students with disabilities to pursue STEM fields as a career. From 2011-2015, the eighth-grade National Assessment of Educational Progress (NAEP) science scores for SWD remained stagnant at 124, while general education students maintained 158. Both scores are far below the proficiency baseline, which is 170 (See Figure 2; National Center for Educational Statistics, 2015).

Figure 2

NAEP Science Scores, 2011-2015

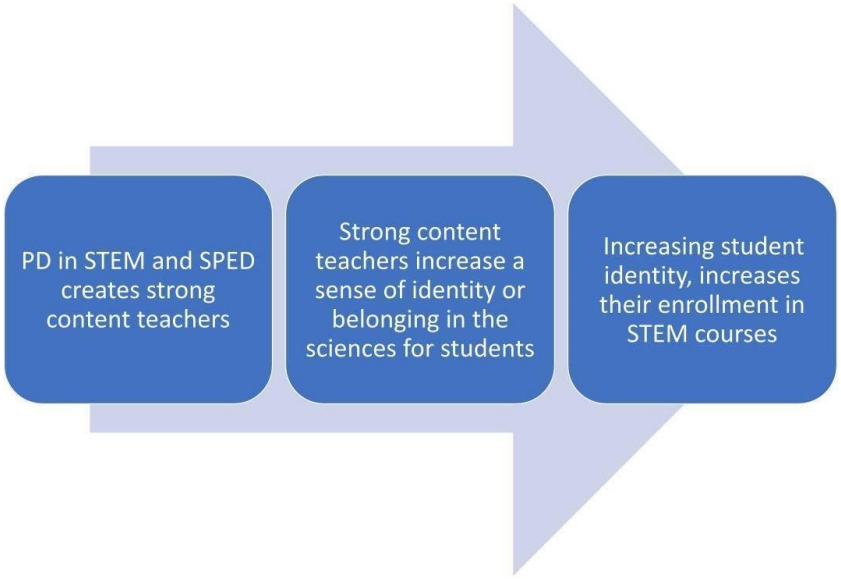


Note: Students with Disabilities (SWD). General Education Students (GenEd).

Fisher (2017) replicated these results by examining Florida's standardized testing in eighth-grade science. A statistically significant difference was found between the scores of general education students and students identified with disabilities. These differences could be attributed to the assessment itself, but they also suggested that further research is needed in the delivery of STEM content to SWD. PD is needed for teachers to learn techniques that work to increase achievement in STEM subjects. PD in STEM education with a special education (SPED) focus may increase teacher confidence in both areas, which can result in more inclusive practices for all learners (Figure 3).

Figure 3

Teacher Confidence Increases Student STEM Identity



Researching PD designed to increase student STEM experiences through confident teachers may alleviate this struggle. This case study examined a PD program aimed at collaborative teams of teachers in STEM classrooms to evaluate whether the program increased teacher confidence in their abilities to deliver STEM content to students with disabilities (SWD).

Inclusion in STEM Careers

It is essential to create more inclusive STEM classrooms that build STEM identity because the United States Department of Labor (2019) predicted 140,000 vacant engineering jobs between 2016 and 2026. Expanding the perception of who belongs in STEM fields to include more women, minorities, and persons with disabilities can help fill these positions while also addressing the needs specific to the diverse population of the United States. Diversity in the STEM workforce is needed to increase innovation and accessibility in the country's continuously evolving technology. For example, voice recognition software needs to be coded by male and female speakers of differing abilities, ethnicities, and accents to train the software

for a wide range of users (Hill et al., 2010). People with physical disabilities are essential in designing products that assist in mobility and have been consulted by General Motors for their fleet of accessible vans and vehicles (General Motors, n.d.). Additionally, Hong and Page (2004) found that more diverse groups were better able to solve problems in optimal ways than groups that were more homogenous in makeup; another benefit of heterogeneity in STEM fields.

Influences on Building Positive STEM Identities

Identity formation begins at a very young age and encompasses many aspects, including race, class, gender, and ability. It is influenced by internal and external factors like family, community, and society (Bronfenbrenner & Evans, 2000). The value a person believes they can contribute to a field helps build their identity and allows them to feel a sense of belonging with a specific group of people. If the group consists of STEM specialists like scientists, engineers, or mathematicians, a person may feel that they, too, are a “STEM person.”

The sense of value from knowing that their unique perspectives and inputs are respected begins in elementary and middle school when student identity is being built. Therefore, it is vital to create classrooms that invite students of all abilities to engage with STEM activities. In order to pursue higher level STEM coursework and careers, students must be able to visualize themselves as STEM people and feel that they can contribute positively in these fields. Students with higher science self-perceptions, for example, are more likely to take additional science courses than are students with lower science self-perceptions (Aschbacher & Ing, 2017).

Universal Design for Learning

Research on the best practices that teachers should employ in their classrooms indicated that UDL builds positive learning environments for SWD by using the strategies of multiple means of representation, engagement, and action and expression to motivate, deliver

instruction, and assess learning (Cast, 2018). Waitoller and King Thorius (2016) see UDL as a way to disrupt the notion that there is a bell curve where students are on extreme ends of ability and that teaching should be centered on the majority of students while the outliers need special resources to access the mainstream. They critique teaching from a narrow mid-point and suggest meeting all learners by starting with a broader range of abilities in mind. Instead of modifying an assignment only for SWD, teachers can create an assignment that meets the needs of all students from the very beginning.

Multiple Means of Engagement and Representation (CAST, 2018) encourages teachers to use systems thinking when teaching problem-solving. Teaching with the bigger picture helps students make connections and reinforce previous learning, thus providing the needed scaffolding for SWD. Complex problem solving can be difficult for SWD due to issues with the cognitive load, which is the interplay of working memory and long-term memory (Sweller, 1990). Using real-world examples allows SWD to access STEM content more readily (Scalise et al., 2018). Teachers can make science concepts more accessible by providing multiple ways for students to learn the material. Conceptual change, including building mental models of phenomena, takes time and reinforcement (Lynch et al., 2007). Allowing students to complete learning tasks that fit their needs and abilities and varying the lengths of the lessons helps build positive STEM identities by avoiding frustration and boredom (Basham & Marino, 2013).

UDL fosters access to marginalized learners through structures and roles that sustain and honor students' identities. These parallel pathways to understanding should be encouraged so students can determine their strengths and weaknesses in different learning environments. Helping students know when to employ accommodation strategies can help them continue higher-level STEM coursework (Mutch-Jones et al., 2012). This method can help them self-identify as problem solvers and users of STEM in practical ways. Additionally, employing UDL makes lessons usable, accessible, and inclusive without additional adaptations when possible

(Burgstahler, 2020). A central tenet of UDL is that the student is best positioned to understand their own best learning methods.

Teachers can set the tone for inclusivity by incorporating tools and equipment that encourage use by all students regardless of ability, which sends the message that all students are valued in the STEM classroom. The PD may include training for teachers in aspects of special education often overlooked for general education teachers like assistive technology (AT) used for communication. When properly trained, general education teachers integrated more AT into their classrooms, which increased communication and positive interactions between the teachers and the students (Bargerhuff et al., 2010). The direct training in AT also led to a positive increase in teacher attitudes towards teaching students with disabilities.

Inclusive lesson design is also critical to see a shift in STEM performance for students with disabilities. Educators who plan lessons based solely on standards within the mandated curriculum are not considering the full scope of the learner because this practice does not address the unique learning abilities or strategies that SWD may bring to a classroom. Allowing students, the flexibility to reflect on their learning and making tasks relevant to them reduces barriers to education and mirrors CSP's attendance to relevance and reflection of one's place in the broader schema.

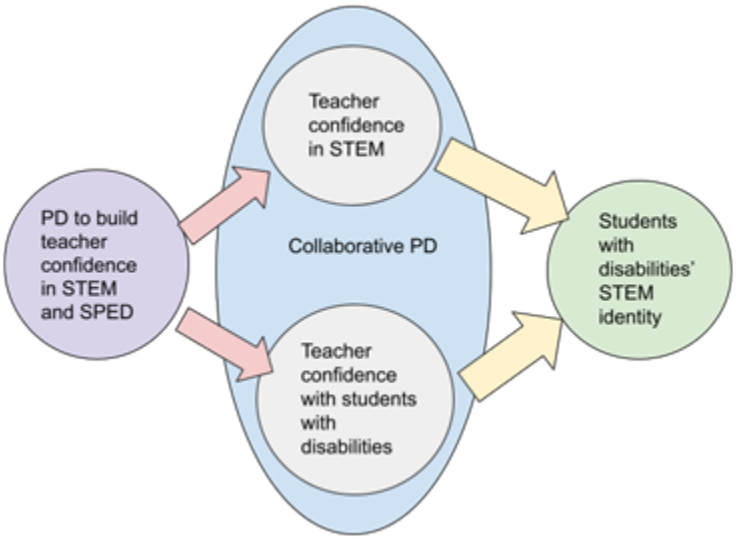
Elements of Professional Development

Williams et al. (2018) found minimal overlap in cross-certification between STEM teachers and SPED teacher qualifications, particularly at the secondary level. The gaps of each teacher must be filled to meet the needs of all students. For this reason, PD for general education STEM teachers that explores the best practices for teaching SWD is as important as PD for SPED teachers to strengthen their science comprehension. When both types of teachers receive PD, the needs of the whole student are more likely to be met. Fisher (2017) discussed how the confidence level of teachers in both STEM and SWD needs to increase in order to create more inclusive classrooms. The collaborative approach to PD that includes both the

content and special education teachers helps build trust and confidence between the teachers (Mutch-Jones et al., 2012). Teachers who attended PD as a team of collaborators were better prepared to meet the needs of all children in the classroom (Bargerhuff et al., 2010; Israel et al., 2013). This partnership can help address the students' abilities and improve student understanding and confidence in STEM subjects. Flexible content delivery can be accomplished through collaborative teamwork. By focusing PD on teams of teachers delivering STEM content, more SWD have the opportunity to create positive STEM identities, which may lead to more diversity in the STEM fields (Figure 4).

Figure 4

Collaborative PD Affects Student STEM Identity



Note: The diagram shows how PD designed to increase teacher confidence in both SPED and STEM increases confidence in both when conducted in a collaborative setting. The ultimate goal is to increase SWD's STEM identities.

PD that focuses on students' abilities can help teachers change attitudes about meeting the needs of all students. Bargerhuff et al. (2010) found that teachers either had lower expectations of SWD or were concerned with this population reaching their frustration level too

quickly. After teachers attended a PD to familiarize themselves with assistive technology to better educate their SWD, their positive interactions with students with severe disabilities increased. These teachers then advocated for student accessibility in all classrooms. Prior to the PD, the lack of teacher confidence in their training and preparation to address the needs of the students hindered their confidence to deliver content and was a barrier to building relationships.

Confident teaching in STEM subjects comes from teachers with sound scientific knowledge. Secondary educators are more likely to hold a degree in their subject area, while elementary teachers are more generalist in their studies (Garet et al., 2001). Therefore, elementary teachers' comfort levels with STEM topics are likely more varied than secondary teachers. Less prepared teachers spend less time teaching science, which lessens student exposure to science content. Research by Garet et al. (2011) has shown that increased PD for teachers in STEM subjects increased the amount of time spent teaching science and math, but Trygstad et al. (2013) found that 60% of teachers spent less than 6 hours in science PD over 3 years.

Studies on specific STEM PD have found some best practices for teacher outcomes (Adamson et al., 2013; Affouneh et al., 2020; Cuevas et al., 2005; Johnson, 2011; Kensinger, 2012). They stressed the importance of teachers being given time to learn new technologies and the resources needed to purchase them (see also Yang et al., 2020). Johnson (2011) found that sustained PD that had a duration longer than one week was more likely to be implemented by teachers. However, there are gaps in the literature about teacher PD programs that address the multiple levels of ability in the science classroom.

The Current Study

To address the gap in the research about collaborative approaches to professional development that focus on both STEM content and SWD, the Zero Barriers in STEM Education (ZBSE) was developed by the Smithsonian Science Education Center (SSEC). The ZBSE

program was piloted as a year-long collaborative PD that focused on science content and delivery methods for SWD. The curriculum was designed by the SSEC and included materials and additional resources on force and motion lessons for the teachers.

This case study aimed to identify changes in teacher confidence and attitudes toward teaching STEM to SWD following their participation in the ZBES. The interview protocols and research questions were developed after an initial analysis of the August 2020 presurvey and the final postsurvey in May 2021. These two documents were chosen because they covered the entire length of the PD, from start to finish. Examining the surveys, action plans, implementation logs, and program evaluation survey and conducting interviews led to a deeper understanding of the participants' confidence in their ability to teach STEM content to SWD. The final interview added perspective on how the participants' attitudes and confidence were affected after being in person to implement the program for the 2021-22 school year.

The research questions were:

RQ1: How has the Zero Barriers in STEM PD impacted teacher attitudes toward meeting the needs of SWD in the classroom?

RQ 2: How has the Zero Barriers in STEM PD affected teachers' implementation and understanding of the tenets of Universal Design for Learning?

RQ 3 How can the Zero Barriers in STEM PD be improved for future iterations?

A pragmatic framework was used to research this issue, which analyzed how general education teacher attitudes toward teaching SWD were affected by targeted training on effective teaching techniques for SWD in the science classroom. This analysis could assist both private and public groups in developing PD that effectively builds teacher confidence in teaching SWD in STEM classrooms. In this study, interviews were used to test Garet et al.'s (2001) theory that more PD in special education and STEM improves teachers' attitudes toward teaching both the

subject and the population. The interview questions were designed to help answer how the attitudes and confidence of STEM teachers of SWD were affected by attending the ZBSE. In addition, the research sought to discover what barriers remained after attending the PD.

The literature review in Chapter 2 explores the various aspects and theories employed in the ZBSE program. It also presents research on effective PD practices that may influence teacher perceptions following the training. Finally, an argument is made as to why teacher confidence in STEM teaching is vital in building student STEM identity.

Chapter 3 describes the study's participants, the study setting, and the documents explored. This chapter also describes the rationale behind the methods used in this mixed methods case study. The results are presented and analyzed in Chapter 4. The conclusions and recommendations based on the implications will be explained in Chapter 5.

Chapter 2: Review of Literature

Examining how a teacher's confidence in their ability to teach STEM content to SWD requires combining many aspects of psychology, education, and pedagogy for both children and adult learners. Positive STEM identity is influenced by reinforcement in a student's STEM efforts. To avoid barriers in building STEM identities, students must be encouraged to see themselves as a 'STEM person.' Even with the student as the endpoint, it is important to acknowledge how teachers as individuals have been influenced by STEM in their own lives and how this influence may impact their ability to reinforce the budding STEM identities in their classrooms. Teacher confidence in teaching STEM concepts and SWD affects their ability to inspire students in STEM subjects. Teachers certified in SPED may need additional training in STEM subjects and vice versa. How PD is presented to teachers in either discipline influences the teachers' confidence levels, which affects their ability to implement the training.

Identity Formation

Bronfenbrenner and Evans (2000) posited the bioecological theory of human development, which provides an essential understanding of the influences on identity. They described many developmental systems or environments that impact children as they develop. The researchers postulated that each system influences the other systems. These systems are arranged from smallest to largest, beginning at the microsystem, mesosystem, exosystem, and finally, the macrosystem. One's microsystem develops from personal interactions at school, home, or places of worship. This system includes peers, siblings, parents, and teachers. The mesosystem is where two microsystems interact. Examples could be participating in scouts or recreational sports with classmates. The exosystem is broader, encompassing the entire school district. It is influenced by adults that the child may not come in direct contact with, like the superintendent of schools. The most extensive system in Bronfenbrenner and Evan's theory is the macrosystem, where cultural beliefs, social expectations, and gender roles, as codified by

ones' culture or society, influence how individuals view their place in STEM or other career areas.

Heaverlo et al. (2013) hypothesized that the exosystem impacted girls' interest and confidence in math. In this instance, the exosystem was composed of the microsystem's teacher influence, family STEM influence, and extracurricular STEM involvement along the macrosystems of race and region. If using this hypothesis, one might speculate that classrooms should be designed to increase confidence allows students with disabilities to build a positive STEM identity beginning in elementary school. Building this foundation of identity at the microsystem level provides a firm base for student STEM identity formation. Encouraging children to make observations and follow curiosities helps develop positive attitudes toward inquiry and scientific thinking.

Creating and maintaining a school community where students treat each other with respect was found by Robinson and Lubienski (2011) to be crucial to student success. The mesosystem of schools and communities should be mindful of messages that are sent about who belongs in STEM jobs with inclusive literature and illustrations. Every effort should be made to make accommodations available in every classroom, not only the SPED classes. When students are not metaphorically sent down a long hall to a small room with few peers but instead can join the general education class, they receive the message that students with varying functional abilities are welcome everywhere. Rainey et al. (2018) found that when students felt part of the STEM community and were valued, they were more likely to continue in that field.

Interest vs. Ability

Ability and interest also affect a student's identity, but they are not always reliant on each other. A student may develop a high self-concept in STEM subjects regardless of their ability in either math or science, as found in a study by Wang et al. (2017). The researchers found that having high ability in STEM at the high school level translated into an increase in an individual's likelihood of pursuing a STEM career. However, a strong self-concept in math but a low ability

did not hinder one's employment in STEM careers. In fact, Wang and Degol (2017) found that a student's interest in STEM was more important than ability when deciding on a STEM career choice. Therefore, content should be coupled with lessons on perseverance to increase self-concept regardless of any innate ability. Capobianco et al. (2015) also found that introducing engineering courses in the early elementary grades positively influenced students' self-perceptions of ability in STEM subjects.

Resilience and Hard work

Teaching resilience in a classroom can inoculate students against negative perceptions of ability when content gets difficult (Yeager & Dweck, 2020). A classroom with an emphasis on performance goals rather than on cooperative or relative learning generates students who are more likely to give up when math or science gets difficult (Wang & Degol, 2017). A growth mindset is more easily maintained when there is less competition in a classroom. Being responsive to assisting students with difficult lessons immediately (before students shut down) while aligning lessons with relevant societal issues was found by Wang and Degol to increase student engagement in STEM learning.

Shifting the classroom focus to hard work rather than intellectual brilliance sends the message that all children can succeed in STEM topics (Meyer et al., 2015). Helping children develop a growth mindset and refuting the idea that math and science ability is innate rather than something learned through hard work was fundamental to improving STEM confidence levels (Degol et al., 2018). Along these lines, teachers must carefully use the word "failure" regarding engineering education. Using the engineering design process in the classroom embraces testing to failure to learn about the limits of a design, thus building perseverance in students when used correctly and not as a way to indicate errors in thinking (Lottero-Perdue & Parry, 2017).

There can be a disconnect between achievement and perception of knowledge also leads to a lack of belonging (Rainey et al., 2018). It was found by Rainey et al. (2018) that

females who received less than an “A” grade considered it as having earned a bad grade, resulting in low confidence despite passing all courses. Research has shown it may be too late for girls to change their sense of belonging in STEM subjects beginning in middle school when electives are chosen. Therefore, focusing on building these identities through elementary experiences is important (Capobianco et al., 2015).

Barriers to Building STEM identity

Without positive programs and interactions in place, barriers to building STEM identities can arise. Several studies have shown how internal and external stimuli influence student perceptions of who belongs in a certain space (Capobianco et al., 2015; Cheryan et al., 2015; Taylor et al., 2017). Rainey et al. (2018) found that these intersection points were a possible barrier to building STEM identity when they studied the effect of race and gender and how a sense of belonging is needed for underrepresented groups to persist in STEM courses.

For many students, stereotype threat or the “fear confirming negative stereotypes of their group” lessened their sense of belonging when they were in the minority by race or gender (p. 2). Gendered classrooms discourage girls from taking computer science (Master et al., 2016). To build a more positive STEM environment, instructors should be cognizant of the messages sent explicitly or implicitly about who belongs in the field (Cheryan et al., 2015). This unwelcome feeling can be alleviated by increasing depictions of persons of all abilities, races, and genders, building a sense of belonging in STEM classrooms.

Another barrier to student STEM identity development is teacher attitudes toward student learning, which can take the form of low expectations based on race or ability (Taylor et al., 2017; Timmons-Brown and Warner, 2016). These low expectations may lead to a students’ sense that they did not belong in that classroom. STEM skills like coding can and should be taught to students of all abilities, with extra time and support for all students to have the same opportunities (Taylor et al., 2018). Teachers who are confident in their abilities to teach STEM content to all students impart this sense of confidence and belonging in their classroom.

PD to Improve Teacher Confidence in STEM

Researchers have found that a teacher's lack of content exposure negatively affected their confidence in teaching STEM content (Bilican et al., 2021; Garet, 2001; Trygstad et al., 2013). The National Science Teacher Association (NSTA), upon which the Council for the Accreditation of Educator Preparation (CAEP) relied for the 2018 teacher preparation standards, defines "qualified" elementary teachers as those having college courses in life, Earth, and physical sciences (NSTA, 2017). Five percent of preservice teachers had taken zero classes in any of those topics. Only one third of the teachers were "sufficiently qualified," defined as having taken each science discipline. Elementary school teachers had few college courses in STEM fields, as seen in Table 1.

Table 1

Percent of College Science Coursework by Grade Level Taught

Grade taught	Engineering	College Chem or Physics	College Bio & Earth & Physical Science
K-3	1%	> 50%	30%
3-5	2%	> 50%	30%
Pre-Service	N/A	N/A	5% have none of these

Note: Data tabulated from Trygstad et al., 2013.

Only 1% of K-3 and 2% of grades 3-5 teachers had taken a college engineering course. Less than 50% of elementary teachers had taken a college-level chemistry or physics course. Due to this lack of familiarity with basic science concepts, preservice teachers in a science teaching methods course needed to be taught basic science concepts (Bilican et al., 2021). Unsurprisingly, over 70% of teachers across grade levels felt that they were not adequately prepared (Trygstad et al., 2013). When the amount of preparation is compared to teacher confidence levels, only 33% of grades 3-5 teachers and 44% of K-2 teachers felt very well prepared to teach science.

A teacher's confidence in their abilities to teach STEM content influences student achievement and self-perceptions of their abilities. Wright et al. (2020) found that students had the lowest achievement levels when little to no science PD was provided to the teachers. Student scores also correlated to the number of hours and amount of time teachers had training on science concepts (Garet et al., 2001). Trygstad et al. (2013) found that 60% of teachers spent less than 6 hours in science PD over the past 3 years. When teachers profess to a class that they do not really "get" science or math, girls shut down and began to think that they, too, were not good at those subjects (Robinson & Lubienski, 2011). These feelings of inadequacy may continue into middle school, when girls tend to lose interest in pursuing higher level sciences, including science electives (Doerschuk et al., 2016).

Comprehensive science teacher preparation, whether in college courses or through PD, leads to enduring STEM experiences for students. A mitigation strategy to this lack of college-level science education is to increase the amount of time teachers spend in STEM PD (Garet et al., 2001). When the PD focused on inquiry learning, the science performance of all genders increased (Kensinger, 2012). More inquiry-based strategies have also been shown by Heaverlo et al. (2013) to improve girls' engagement in STEM learning. These studies show that more science PD is needed for elementary teachers to ensure that students are exposed to high-quality science content. Several studies showed similar teacher success following either generalized or STEM-specific PD programs (Affouneh et al., 2020; Brand, 2020; Johnson, 2011; Lynch et al., 2007; Taylor et al. 2017). In contrast, Adamson et al. (2013) found that science content PD did not improve teachers' science literacy, so further research is warranted.

General education teachers need support in providing adequate and appropriate tools and pedagogy to meet all learners in their classroom. This type of confident teaching comes from teachers with sound scientific knowledge and active lessons that elicit higher level thinking and collaborative problem-solving that mirrors how scientists solve issues. PD can address

science content or special education strategies, but there is a gap in the research on programs that address both.

PD Topics to Improve Inclusive Teaching of STEM

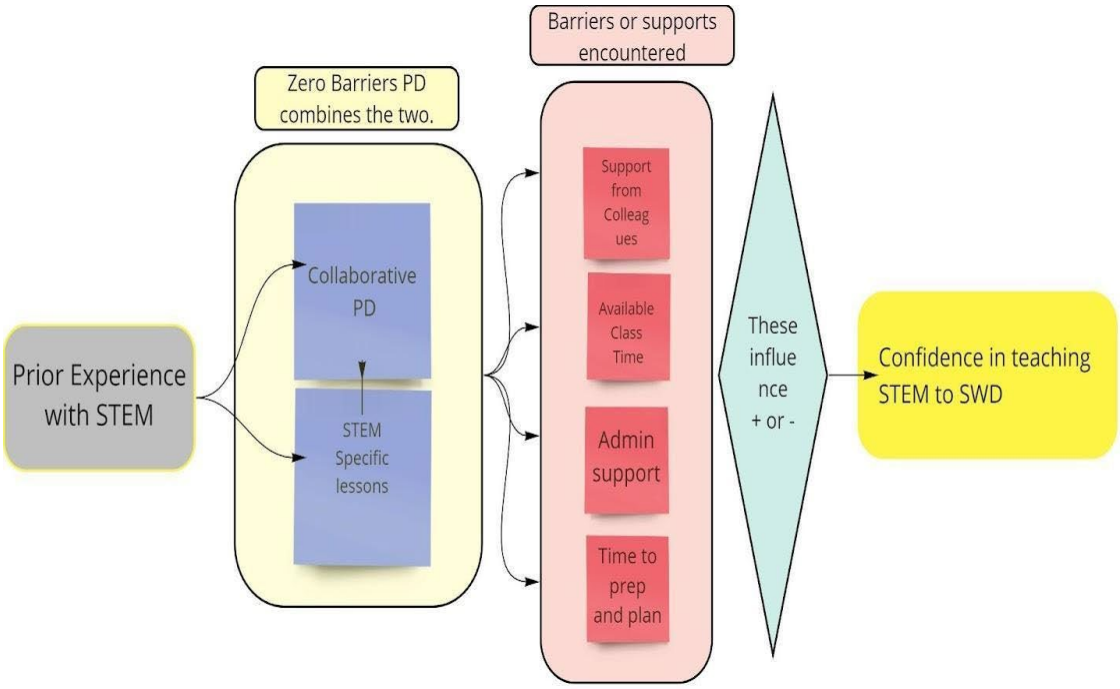
To increase teacher confidence in teaching both science and SWD, PD should include science content coupled with practical applications of working with many different populations and abilities.

Concept Map

Teachers bring their prior personal experiences with STEM to their teaching practice (Olsen, 2008). The number of supports and barriers encountered after PD can influence their confidence and attitudes (Figure 5).

Figure 5

Influences on Teacher Confidence in Teaching STEM to SWD



How Should the PD Be Implemented?

Studies have shown that there is great complexity in designing effective PD for the many skills and personalities of teachers that are present. Teachers who are resistant to PD may be the ones who need it the most. Yang et al. (2020) and Affouneh et al. (2020) found that teachers of technology and female teachers were more likely to have positive attitudes toward integrating and implementing STEM lessons. An analysis of specific STEM PD programs by Brand (2020), Adamson et al. (2013), and Johnson (2011) found that using a constructivist team approach that focused on sustainable frameworks that teachers could modify to meet the needs of their students during long-term PD had the best results for teachers. Adamson et al. (2013) found an increase in the teachers' ability to connect learning to real-world activities and were better able to identify students' difficulties during instruction after their team PD. More practical lessons were also essential to continuing the pedagogical frameworks presented. Other studies have modeled how science pedagogy leads to science content knowledge, thus increasing teachers' higher level thinking skills through discussion and questioning techniques (Hanley et al., 2020).

Collaborative Partnership PD

Team building is essential to fill in the gaps brought by each teacher to meet all the needs of the students. This partnership can assist in improving student understanding and confidence in STEM subjects. Flexible content delivery can be accomplished once collaborative teachers have considered strengths and weaknesses of their learners. Schools should foster team efforts that build rapport increase content and SPED best practices for both the special education teacher and the content teacher.

Researchers have found that teachers who attended PD as a team of collaborators were better prepared to meet the needs of all children in the classroom (Bargerhuff et al., 2010; Israel et al., 2013). The studies encouraged schools and administrators to support more collaborative partnerships between the many adults supporting students with disabilities. They encouraged dual participation between the teachers and their collaborative partners. Building these

relationships allowed the teams to discuss and address specific students' needs, resulting in faster interventions for students when needed (Mutch-Jones et al., 2012). Teachers were willing to change entire units to address student needs and to align better with science content. This study showed the importance of structured co-planning and an analysis of lessons between the teams of teachers.

Barriers to Effective PD

Studies have found a number of barriers to PD programs, both in general and specifically to STEM PD. The increased accountability on standardized assessments and a lack of support to meet with peers to discuss curriculum and pedagogical strategies at both the school and district levels were barriers to STEM integration at the elementary school level (Affouneh et al., 2020; Johnson, 2011). There also can be a disconnect between the pedagogical and content knowledge being shared with the teachers which makes it difficult to apply the PD in a classroom.

Along with time to plan as a team, crucial to the success of a PD is teacher support both in materials and in guidance on the best delivery of content. A 2020 study by Hanley et al. overcame implementation barriers by providing financial support for teacher training and planning time during the school day, as well as grant funding for the materials. Yang et al. (2020) also found that their participants expressed a desire for more training time to implement the new initiatives and compensation for learning that occurred outside of school hours so that they could master the technology and content presented.

A barrier beyond the control of the researcher is teacher and or administration attrition, which can severely limit the effectiveness of a PD if the new administration no longer supported the initiatives (Yang et al., 2020). Johnson's (2011) study also had difficulty controlling for teacher attrition and the impact of teacher movement between grade levels. When moving grade levels, the science concepts taught may differ considerably, thus affecting a teacher's science literacy and confidence levels. One year may focus on life science, while the following

year focuses on physical science concepts. See Table 2 for a breakdown of both barriers and supports.

Table 2

Barriers and Supports for STEM PD

Effect on Teacher Confidence	Negative (Barrier)	Positive (Support)
Equipment funding (Hanley et al., 2020)	-	x
Planning Time (Johnson, 2011; Affouneh et al., 2020; Yang et al.,2020)	-	x
Movement of teachers through grade levels (Adamson et al.,(2013)	x	-
Overall Teacher Attrition (Adamson et al., 2013; Johnson, 2011, Yang et al. 2020)	x	-
Increased accountability on standardized tests (Johnson, 2011)	x	-
Mandated PD (Affouneh et al., 2020)	x	-
PD during contract hours (Affouneh et al., 2020)	-	x
Teachers with some previous skills (Affouneh et al., 2020)	-	x
Administrative support of the PD (Affouneh et al., 2020; Yang et al., 2020)	-	x
Flexible time and location (Affouneh et al., 2020)	-	x
Additional training time (Yang et al., 2020)	-	x

Due to the various manifestations of barriers, not all the teachers in PD studies fully implemented the interventions for a true assessment of their value. Supports to teachers, as found in Table 2, may alleviate the negative results of the barriers, but little research has examined how each influences the other. Ultimately, designers of PD should be aware of

barriers that may be present and how specific supports can assist the implementation of PD for teachers. The ZBSE utilized many supports while being unable to foresee the barrier that the COVID-19 pandemic presented to the teachers.

The ZBSE PD

Both general and SPED teachers need additional training to apply pedagogically sound techniques to teach STEM content to SWD. The ZBSE PD was a year-long pilot study conducted from 2020 to 2021 by the Smithsonian Science Education Center (SSEC.) The goal of the ZBSE PD was to increase the confidence and attitudes of teams of teachers working together with mainstreamed SPED students in a collaborative classroom. It incorporated many of the attributes of effective PD found in this literature review. The program was collaborative, with teacher leaders from science content and special education as well as district and school administrators. The PD focused on UDL practices and STEM content. The teachers were provided with materials and curriculum as well as support throughout the year.

The PD began with an application program through a local urban school district directed at teams of STEM and SWD teachers and administrators. The age groups taught by the teachers ranged from PK-8 (Table 3). Twenty-five teachers were enrolled in the Moodle course designed by the SSEC. Fourteen teachers filled in the August 2020 presurvey. Of those who filled in the survey, most participants were general education teachers with representation at each grade level. SPED teachers made up only 14% of the participants and represented only Grades 3-8. One teacher who marked “Other” was dually certified in both general education and special education. Another teacher was certified in STEM education and chose “Other.” The last teacher who chose “Other” described himself as having “taken special education courses and taught different types of special education classes, which would mean belonged in the Special Education teacher category,” but he was a history teacher which may explain why he chose “Other.”

Table 3

Teacher Certification by Grade Level and Specialty

Grade Level	General Education	Special Education	Other
PK-2	3	-	-
3-5	4	1	1
6-8	2	1	2

Teams of teachers were trained in both STEM content and collaborative partnerships between special and general education teachers who would be working together in kindergarten through eighth grade. The ZBSE program consisted of a kickoff week of sessions that introduced teachers to both the curriculum and the pedagogy behind its implementation. Initially, the program was going to include in-person PD with representatives from the SSEC conducting hands-on training with the teachers. However, due to the COVID-19 pandemic, not only was the PD changed to virtual, but most of the teachers were not able to use the materials in person with the students.

The ZBSE PD was designed to have in-person training on materials and lessons that were provided to the teachers. Unfortunately, COVID-19 hit and the schools went virtual. In August 2020, the ZBSE kick-off week was switched to virtual training. It was 4 days of interactive training lessons on UDL, Carolina Science resources, a Smithsonian curriculum unit for either grade 4 or 8, and a planning day with both small and large group discussions on strategies for implementing the program in their classrooms. The four primary days had two hours of synchronous work and an asynchronous assignment. The August pre- and postsurvey data was collected at this time.

Throughout the 2020-21 school year, participants were invited to attend refresher courses and curriculum jams. SSEC staff contacted teachers to see what support was needed throughout the schoolyear. Implementation logs were requested in November 2020, February

2021 and April 2021. Teachers were also invited to participate in three refresher PD's during the school day with substitute coverage provided by the district for them to attend. The first was in the beginning of April, which retaught the curriculum units for fourth and eighth grades. Later that month, UDL was refreshed with guest speakers. Finally in May 2022, the final weekend PD was a time for reflection on what barriers teachers found while providing time to create action plans for further implementation in the 2021-22 school year.

Chapter 3 Methodology

This case study analyzed the preliminary findings of the ZBSE PD on teachers' confidence in teaching STEM to SWD to determine if there was an overall change in teacher attitudes toward teaching STEM to SWD. There were two sets of pre and post surveys. One pair was administered after the first week of PD in August 2020. The second pair was administered after the weekend PD in May 2021. There were only two teachers who attended both sessions. To gather insights across the entire length of the PD, the teachers' pre-surveys taken in August 2020 were compared to their post-surveys at the end of the program in May 2021. The data from these was used to create questions about the program that could provide clarity on teachers' attitudes and confidence following the PD. The responses were used to create research questions that center on the impact of the PD on a teacher's ability and attitudes in teaching STEM to students with disabilities. For the final project, the pre- and post-surveys for only August were analyzed, which allowed for a larger response size of 15 participants. The May pre- and post-surveys were analyzed as a separate document and only had two respondents. In addition, the implementation logs, program evaluations, action plans and the interviews were added to provide more data to the case study.

Researcher Bias

I served as an intern for the SSEC for part of the pilot study and presented the supplemental webinars. This allowed the data to be analyzed as a quasi-outsider. However, it may also have introduced bias as a facilitator in the program. My facilitation of the program may have influenced the participants, causing reactivity on the individuals (Maxwell, 2013). This was alleviated by viewing the analysis of the data as a way to improve on the program rather than as a way to find fault with it. This relationship may have helped to further establish trust in conversations with participants as they may remembered my presentations. However, it also may have discouraged negative comments about the program. To address this during analysis, any conclusions were tested by looking for additional evidence that may invalidate the findings

and by using Maxwell's (2013) checklist for validity. Participants were asked to validate the conclusions to avoid my misinterpretation of the interview (member checking).

A second reviewer was added to address researcher bias. The second rater scored the interviews using the codebook I created. Negative cases and discrepant evidence were identified and evaluated for any impact on the conclusions. When using multiple data sources (surveys, short answer responses, logs, and interviews), triangulation can occur, which lowers the risk of bias due to one specific method (Denzin, 1978).

Participants and Recruitment

The subjects of this case study were the ZBSE PD participants who completed the August 2020 pre- and post-surveys. Participants from the initial weeklong session were invited to add insights to the program via a one-on-one virtual interview. Convenience sampling was used to select study participants. I contacted the participants via email. The participants were provided with a VCU consent form (Appendix F). They were given a $25 gift card as an honorarium for their time.

The participants were bound by teaching in the same urban school system with similar demographics. They taught prekindergarten through eighth grade classes. Half were general education teachers. Two were certified in SPED. One was dually certified in general education and SPED. Their experience in education ranged from 5 to 26 years, with a majority having 11-14 years. Seven of the 15 teachers had some SPED training.

Design

In this study, axiology was influenced by the belief that all children can learn science and that teachers need the right tools and techniques to reach all learners. Ontologically, teachers are undereducated in the best practices of teaching STEM to SWD. The epistemological viewpoint was that gathering information on a PD program designed to increase teacher confidence in teaching STEM to SWD would increase the best practices of future PD programs. A mixed-methods case study approach examined the relationships between these beliefs (Terrell, 2016).

Data Collection

Documents included in this case study were the pre- and post- surveys from August 2020 and May 2021, the final interview transcripts, the implementation logs, the team action plans, and the PD evaluations. A strength of these documents was that they were readily available and stable (as defined by Yin, 2018), as they were collected throughout the program's implementation except for the final interviews. The analysis of the data was unobtrusive and broad. A weakness of using these artifacts was reporting bias by the participants who completed them. The interviews worked to alleviate this bias by allowing teachers to expand on their viewpoints.

The same pre- and post-surveys were administered at the August 2020 PD and the May 2021 PD. Using mixed methods to analyze the survey results increased the validity, as the Likert questions were then asked in open-ended form. The preliminary analysis used the presurvey data from the August PD and the postsurvey data from the May PD to create research questions that addressed any changes over the course of the school year and as a result of the PD. However, only two participants attended both the fall and the spring PDs. If the 15 responses from the August 2020 PD are averaged and compared to the averages of the two participants in May 2021 postsurvey, the construct results decrease by .2 - .7 points. Therefore, the preliminary analysis included only the presurvey data from August 2020 and the May 2021

postsurvey data of the two participants. This choice allowed analysis of the data using the pre- and postsurvey data from August as one data set and the pre- and postsurvey from May as a separate data set.

Frey et al. (2020) used a case study to effectively describe a STEM development program for preservice teachers. Their study found that the exposure to many STEM teaching techniques increased preservice teachers' understanding of pedagogy. Additionally, Aydin (2020) used a case study method to understand in-service STEM PD for elementary school teachers. Aydin analyzed surveys, diaries, and lesson plans to glean information about how teacher understandings of STEM integration changed over time. These successful qualitative case studies demonstrated the importance of adding participants' voices to their experiences (see also Creswell & Clark, 2018). In this study, the teacher pre- and post-surveys alone could not provide enough information to determine how teacher attitudes had changed after participating in the PD. Therefore, multiple sources of evidence were used to add data to this contemporary real-world case (as recommended by Yin, 2018).

This study took the form of a single-case embedded research study (Yin, 2018) to produce an analysis of whether the ZBSE PD positively affected teachers' attitudes. The single case was defined as this specific PD program and how the attitudes may have changed over time, including post-PD changes. The subunits were the pre- and post-surveys from August 2019 and May 2021 (Appendix A), interviews (Appendix D), implementation logs (Appendix B), PD program evaluations (Appendix C), and the action plan. Each is explored in the next section.

Pre/Post Surveys

The pre- and post-surveys were developed by the SSEC. They had 25 Likert-scaled questions and three open-ended questions. The Likert scale used a 1-4 scoring range from *Strongly Disagree* to *Strongly Agree* (1-4). There were 11 negatively asked questions and 14 positively asked questions. The Likert-scale questions for the pre- and post-surveys were identical, but the open-response questions in the postsurvey varied slightly. The presurvey question, “Why do you want to take this PD, and what do you expect to learn?” was omitted in the postsurvey. The presurvey question about teaching SWD changed from, “Please describe how you teach SWD in your class. What challenges do you face?” to “What new considerations or challenges do you expect in terms of prioritizing accessibility and inclusion in the new school year?” in the postsurvey.

Implementation Logs

Participants were asked to complete implementation logs throughout the 2019-2020 school year. These logs consisted of 22 Likert-scale questions about their use of the program and the students’ reaction to the program. Five open-ended questions asked about what parts of the project were working well and which aspects were challenging to implement. The remaining nine questions required yes or no responses and pertained to the use of specific techniques that participants were trained on in August 2019; for example, “Manipulatives were used following the Concrete-Representational-Abstract method,” which they had been training on in the summer.

Action Plan

The action plan was created by participants during the May 2020 PD as a final step to consider how the ZBSE PD program could be used in the next school year. Participants decided on a problem statement, then determined activity steps, owners of the steps, and what the expected outcomes might be. Only one team shared their plan with the SSEC to use in the analysis.

Interviews

The interview protocol was developed after analyzing the August 2020 presurvey and the May 2021 postsurvey from the pilot study to determine areas that showed a discrepancy or decrease between the Likert-scale and the open-ended questions. Revisiting these areas through the interview provided insights into how teacher attitudes had changed as a result of the ZBSE PD and possible areas of improvement in the program. The interview allowed for the participants to give feedback on the program and curriculum implementation.

The interviews were semi-structured (see Appendix D) to allow deeper conversations and understanding of the program's impacts, implementation barriers, and successes. The goal was to expand insights into creating impactful PD while exploring teacher experiences implementing the PD. All 15 participants from the August 2020 PD received an email requesting an interview. One participant responded within a week of the first email. The second recruitment email gathered one more participant. The third email also elicited a positive response, but this teacher did not respond to follow-up contacts to set up a time to meet. The consent form was sent electronically to each participant and returned via email (Appendix E). Participants were made aware that if they wanted to end the interview at any time, they could. Participants were asked to restate their willingness to be recorded for the interview. The interview conversation was recorded through the Zoom video meeting platform, which created a transcript that was later analyzed in Atlas.ti qualitative analysis software. The interviews lasted an average of 30-45 minutes. The transcripts were read for clarity and typos and to attribute quotations to speakers. The participants were sent the transcripts to review for accuracy. Only one participant replied with suggested clarifications.

Survey Constructs

The constructs of the pre/postsurvey outlined in the next section were devised by the SSEC to guide their research questions for the pilot study. Their constructs were used to group the questions when developing the research questions for this study. Tables 4 and 5 were used to visualize which constructs increased or decreased from the pre- to postsurvey, which led to the research questions of this study. Because the data only applied to two participants, the results were not statistically significant but increases or decreases in sentiment were used in the formation of the research and interview questions.

Construct 1

"Special Education Training Experience" addressed teacher confidence in their own SPED training. It showed an overall increase of .2 points, suggesting that the teachers grew more confident after completing the ZBES. There were no open-ended questions in this construct. This construct was explored further with Construct 2 in the research questions for this study.

Construct 2

"Thoughts about Special Education Training" showed a decrease of -.6 points, one of the most significant negative changes in the survey. However, there was a disconnect between the Likert-scale and the open-ended answers. In the open-ended question, participants were asked to explain their thoughts on STEM/SWD training for both regular education and SPED teachers. Participant 3 answered, "Training should be required for both the general education and special education teacher to have insight on the student disability to be effective teachers." Her Likert-scale item response was *Disagree* for the postsurvey, down from *Strongly Disagree* in the presurvey.

Participant 2 showed fatigue in her answer to the open-ended question:

> I think it is important for all teachers to receive basic training to support students with disabilities, but it is definitely a collaborative effort. In my opinion, general education teachers are given a lot on their plate and while some strategies can be incorporated, it is important for there to be special education teachers written into a budget to support general education teachers as strategies are constantly changing. Not all strategies fit students and having constant input or support from an additional teacher is always helpful to meeting the needs of all students.

This statement indicates that the participant felt alone in the training. Both participants lacked confidence in their ability to lead the science experiments with the number of students in their classrooms. Participant 2 also expressed concerns about not having enough collaborative support for small groups and modifications: "I often do not get additional supports in the class like math or ELA," and "Too many variables to navigate with the number of students in the space…too many variables to navigate with the number of students in the space."

Overall, Construct 2, "Thoughts about SPED training," asked how the teachers felt about the necessity of training both the general educator and the special educator. RQ 1 sought to discern more information about educator attitudes toward meeting the needs of SWD by asking: "How has the Zero Barriers in STEM PD impacted teacher attitudes towards meeting the needs of SWD in the classroom?"

Construct 3

This construct had four subsections under the umbrella, "Beliefs About Students with Disabilities." Subconstruct 3.1 "Beliefs about SPED students in general" decreased by .5 points. The remaining subconstructs, 3.2 "Beliefs about students with disabilities in terms of learning," 3.3 "Beliefs about students with disabilities in terms of social aspects," and 3.4 "Beliefs about

learning environment with Special ed students" had positive increases in the change in attitude over time by .2 points.

This discrepancy in responses indicates that further questions were warranted to clarify what supports and barriers were found in implementing the ZBSE. RQ 3, "How can the Zero-Barriers in STEM PD be improved for future iterations?" sought to clarify Construct 3.1, "Beliefs about Special Education in General." The two Likert-scale questions in this construct were "Students with disabilities should be included in regular education classrooms," and "All efforts should be made to educate SWD in the regular education classroom." The decrease in these beliefs may be related to barriers encountered while trying to teach the information virtually. The follow-up interview questions focused on practical barriers such as time constraints and inclusive grouping of SWD in regular education classrooms. Probing questions were asked about administrative and colleague support of the techniques learned. These questions were intended to enrich the understanding of teacher perspectives on the ZBSE and how to address barriers with teachers in the future.

Construct 4

"Self-Efficacy and Confidence" remained the same for Participant 1 but decreased by .2 for Participant 2, averaging to an overall decrease of -.1. The open-ended question, "How do you think you can increase accessibility and inclusion in your class?" aligns with this construct. Only one teacher answered in both the pre and postsurvey, which mentions being provided with resources by the school and wanting help to improve family relationships.

Construct 5

"Understanding of UDL," had the most significant negative change over time, with a drop of -0.625. The teacher attitudes trended more strongly in the presurvey, with 14 statements indicating that they understood UDL. There were only five statements marked "strongly" in the post attitude, which may have resulted from fatigue in completing the survey or the school year

overall. The two questions in this construct that brought the average down were written negatively, which may have affected the participant's interpretation.

The open-ended question, "What resources do you think you need to support students with disabilities in your lesson?" was answered by Participant 2 who asked for low cost, at-home resources, manipulatives, and lesson plans in the presurvey but changed this to "Modified curriculum with assessments. Adaptable technology, lesson plans, activities" in the postsurvey. This shows a deeper understanding of UDL practices which was further addressed in research question two.

RQ 2: How has the Zero Barriers in STEM PD affected teachers' implementation and understanding of the tenets of UDL? is based on the SSEC's Construct 5, "Understanding of diversity, equity, and inclusion (DEAI) and UDL," and is used to clarify how the teachers felt about using UDL in the classroom. DEAI is not explicitly addressed in the constructs which are focused more on UDL techniques, but their inclusion opens the door for further exploration of equitable practices in future iterations of the program.

When participants' averages and changes over time were calculated, the overall change over time was identical between the participants, with a negative .21 change (Table 4 & Table 5). This result shows that both participants decreased in overall attitude from August 2020 to May 2021. There is much variation between the participants' attitudes by construct, although there is no case where one has a positive change, and the other has a negative change.

Table 4

Participant 1 Averages and Change Over Time by Construct

Instrument	SPED Training Experience	Thought About SPED Training	Beliefs About SWD in General	Beliefs About SWD Learning	Beliefs About SWD Social Aspects	Beliefs About SWD Learning Environment	Self-Efficacy & Confidence	Understanding of UDL	Overall
Pre 1	2.33	4.00	4.00	3.00	2.00	2.67	3.00	4.00	3.13
Post 1	2.67	2.89	3.00	3.00	2.33	2.67	3.00	3.75	2.91
Average	2.50	3.44	3.50	3.00	2.17	2.67	3.00	3.88	3.02
Change	0.33	-1.11	-1.00	0.00	0.33	0.00	0.00	-0.25	-0.21

Note: Blue indicates a positive change in attitude. Orange indicates a negative change in attitude.

Table 5

Participant 2 Averages and Change Over Time by Construct

Instrument	SPED Training Experience	Thought About SPED Training	Beliefs About SWD in General	Beliefs About SWD (Learning)	Beliefs About SWD (Social Aspects)	Beliefs About SWD (Learning Environ-Ment)	Self-Efficacy & Confidence	Under-standing of UDL	Overall
Pre 2	2.67	4.00	3.00	2.33	2.67	2.33	2.80	3.50	2.91
Post 2	2.67	2.89	3.00	2.67	2.67	2.67	2.60	2.50	2.71
Average	2.67	3.44	3.00	2.50	2.67	2.50	2.70	3.00	2.81
Change	0.00	-1.11	0.00	0.33	0.00	0.33	-0.20	-1.00	-0.21

Note: Blue indicates a positive change in attitude. Orange indicates a negative change in attitude.

Table 6 compiles the information from Tables 4 and 5 to create a color-coded table indicating what constructs decreased from August 2019 to May 2020 and which constructs showed an increase.

Table 6

Beliefs About Students with Special Needs: Overall Attitude Change by Construct

Con-struct	SPED Training Experience	Thought About SPED Training	Beliefs About SWD in General	Beliefs About SWD (Learning)	Beliefs About SWD (Social Aspects)	Beliefs About SWD (Learning Environ-Ment)	Self-Efficacy & Confidence	Under-standing of UDL
Participant 1	0.3	-0.6	-1.0	0.0	0.3	0.0	0.0	-0.25
Participant 2	0.0	-0.7	0.0	0.3	0.0	0.3	-0.2	-1.0
Overall	0.2	-0.6	-0.5	0.2	0.2	0.2	-0.1	-0.625

Note: Table 6 shows the areas in the pilot study where teachers ended with a decrease in attitude and confidence. Blue indicates a positive change in attitude. Orange indicates a negative change in attitude. N=2

Research Questions

The decrease in the Overall averages for Constructs 2, 3.1, and 5 guided the creation of the research questions.

RQ1: How has the Zero Barriers in STEM PD impacted teacher attitudes toward meeting the needs of SWD in the classroom?

RQ 2: How has the Zero Barriers in STEM PD affected teachers' implementation and understanding of the tenets of UDL?

RQ 3: How can the Zero Barriers in STEM PD be improved for future iterations?

Data Analysis

An inductive strategy (Yin, 2018) was used to provide insights into possible relationships between the data in the implementation log, action plans, evaluation surveys, and the interviews.

Code Development

The codebook was developed after reading the interview transcripts and open-ended responses to other documents. Themes were highlighted by finding repeated phrases or words in a constant comparison analysis (Onwuegbuzie et al., 2009). Two main themes that were anticipated were positive and negative attitudes toward teaching STEM. More significant and precise themes emerged through pattern coding, which looks at the percentage coverage and overlaps in codes.

After each interview, memos were kept to capture any immediate threats to validity or parts of the conversation that stood out as important to revisit during analysis. The memos were consulted between interviews for keywords or phrases shared between participants. The memos also tracked significant statements for parallels between the interviews or documents. Memos were also used throughout the project to record thoughts.

Theme Development

Key phrases were written down during the interviews, which served as open coding (Onwuegbuzie et al., 2009). These phrases were compiled via memos to find significant similarities. Selective coding was used to find themes within each research question. Other themes that were noted were the amount of administrator support and familiarity with content topics which were supported by the works of Adamson et al. (2013), Brand et al. (2020) and Hanley et al.(2020).

Validity

The SSEC had initially planned to deliver the ZBSE PD in person. The pandemic necessitated a change to a virtual PD. For this reason, the teachers were not able to practice with the provided materials. This factor may have impacted their confidence in presenting the curriculum to fidelity. The materials included class sets, which were not useful the first year of the PD, as it was virtual.

Another threat to validity was the lack of energy after two years of pandemic teaching. A neutral conversational tone in the interviews, which may have influenced the teachers being interviewed, known as reflexivity (Yin, 2018). Another threat to conducting interviews was that the teachers may have their own biases or not remember the PD training very well. They also may not have been able to express how they had changed their attitudes since the PD. Participants answers were corroborated by asking similar questions in different ways and by using probing questions.

One of the largest threats to validity was participant attrition. As seen in Table 7, participation dwindled to two at the end of the study.

Table 7

Participation by Document

	Document								
Participant number	PD August 2020 Pre-Survey	PD August 2020 Post-Survey	Summit May 2021 Pre & Post	PD Implementation Logs			Summit Action Plan	Summit Program evaluation	Final Interview
				Log 1	Log 2	Log 3			
1	x	x	-	-	-	x	-	-	x
2	x	x	x	x	-	x	x	x	x
3	x	x	x	-	x	-	x	x	-
4	x		-	-	x	-	-	-	-
5	x		-	x	-	-	-	-	-
6	x		-	-	-	-	-	-	-
7	x	x	-	-	-	-	-	-	-
8	x		-	-	-	-	-	-	-
9	x	x	-	-	-	-	-	-	-
10	x	x	-	-	-	-	-	-	-
11	x	-	-	-	-	-	-	-	-
12	x	-	-	-	-	-	-	-	-
13	x	-	-	-	-	-	-	-	-
14	x	-	-	-	-	-	-	-	-

The August 2020 pre-survey had 14 participants. The post-survey had half that number with seven participants. As the unprecedented virtual and hybrid school year (2020-21) continued, the numbers of participants varied. There were six implementation logs that five different teachers completed. Two teachers completed the May 2021 pre- and post-surveys. The same two teachers completed the program evaluation. One participant completed the only

action plan that was submitted. This person had administrators to assist in the development of the action plan, but there were no data points for those who assisted. Of the two participants who attended the May 2021 PD, only one agreed to participate in the interview.

Strategies to Increase Credibility

To increase credibility, in the participants' answers I stated that the goal was to improve the program and would be considering their valuable feedback for future iterations of the PD. It was essential to be thoughtful of the stresses in teaching in these pandemic times. I validated the teachers' attempts to integrate the PD into their classrooms. Saturation was reached when all of the interviews were coded and cross-referenced with the data from the other documents and no new data emerged (Mason, 2010). A second coder coded the two interviews to increase reliability.

Risks and Confidentiality

This study involved minimal risks, meaning that the probability and magnitude of harm or discomfort anticipated were not greater than those ordinarily encountered in daily life. There was the potential risk of losing the confidentiality of the participant's responses. All data were stored as digital files that were password protected to minimize this risk. The records were kept confidential, consistent with federal and state regulations. Only the investigators had access to the data. Pseudonyms are used throughout this report. Data were encrypted and stored on a password-protected computer.

Benefits

Participating teachers were provided a twenty-five-dollar gift card for participation. Their participation contributed to the further understanding of teacher practices of accessible strategies in inclusive classes. The information gained from this study may help to create an equitable and inclusive learning culture.

Chapter 4: Findings

This case study analyzed six sets of documents from the ZBSE PD. The presentation of the results begins with an overview of the documents, participants, and missing data. The codebook development method precedes the results across all of the open-ended questions. General results across all documents are presented by themes and subcategories. Following these results, each document's qualitative results will be examined individually. Here, any statistical analysis from the quantitative portions of the documents will be discussed as part of a mixed-methods summary. Finally, the attitudes of the three participants who attended all the PD sessions or participated in the interview were analyzed to assess the research questions and the overall program.

Document Overview

All of the documents in this case study had a qualitative, open-ended component. Some had an additional quantitative Likert-scale section. The document list in Table 8 specifies which type of data was collected and the number of respondents. Only the August 2020 pre- and post-surveys and the implementation logs had enough data to be analyzed using descriptive statistics.

Table 8

Document List by Type

Document	Qualitative	Quantitative	Number of Responses
August 2020 Pre and Post surveys	X	X	14
Implementation Logs	X	X	6
May 2021 Pre and Post surveys	X	X	2
May 2021 Action Plan	X		1
Program Evaluation	X		2
Interviews	X		2

The August 2020 presurvey had 14 responses, while the August postsurvey had only seven. The implementation log had six responses. The remaining documents (the May 2021 pre- and post-surveys and the program evaluation) had two respondents After the creation of the codebook, each document was analyzed for the four main themes; positive program (PosProg), negative program (NegProg), positive nonprogram (PosNonProg), and negative nonprogram (NegNonProg.)

The open-ended qualitative questions provided context to the quantitative Likert-scale data. The data often converged in sentiment with the quantitative data. For example, Participant 2 wrote in the open-ended portion of the implementation logs, "Using the Smithsonian class Zero Barriers, I was able to refer back to a variety of styles and learning methods." This statement supported her Likert scale response of *Agree* on Question 1.6, "I am confident incorporating Universal Design Learning strategies in my lessons."

Participant 4 had a similar agreement in qualitative and quantitative data. She recognized that "it's hard to have ALL children feel accepted and supported within the classroom virtually," and added that "virtual has been difficult for many of my students." This lack of confidence in reaching her students in a virtual setting was reflected in her score of 3 on the Likert scale statement 1.10. "I think all my students are involved in my class."

Qualitative Data Collection and Analysis

Creating the Codebook

The codebook was developed after reading the interview transcripts and finding themes within. A constant comparison analysis was used to chunk codes into sections (Onwuegbuzie et al., 2009). I used a binary category coding system of positive and negative themes in the axial stage. Once uploaded into the Atlas, a qualitative data analysis software, I used pattern coding to find major themes by looking at percentage coverage and overlaps in codes. Percent coverage in this project is defined as the frequency that a code appears in comparison to the total number of all codes. To address RQ 1, "How has the ZBSE PD impacted teacher attitudes

toward meeting the needs of SWD in the classroom?" and RQ 3, "How can the ZBSE PD be improved for future iterations?" I utilized the codes that emerged under the positive and negative program themes. For RQ 2, "How has the ZBSE PD affected teachers' implementation and understanding of the tenets of UDL," I looked for keywords and phrases like "text to speech" (Participant 2) that represent UDL tenets discussed during the PD sessions throughout the year. Selective coding was used to find themes across the documents.

While coding all the documents, themes outside the focus of the ZBSE program emerged as shown in Table 9. For example, the negative statement "[No] time to teach science" was not related to the program but spoke to a larger issue in education. In order to separate comments about the program from comments about the state of education generally, new categorical codes were created. Positive and negative aspects of the program were coded PosProg and NegProg. Comments outside the program's scope were separated into positive nonprogram (PosNonProg) and negative nonprogram (NegNonProg). If free codes emerged in the document analysis, they were added to the subcategories of the major themes. Not all the subcategories were represented in each theme.

Table 9

Program Codes by Major Theme Across all Documents

Negative Nonprogram (NegNonProg)	Negative Program (NegProg)	Positive Nonprogram (PosNonProg)	Positive Program (PosProg)
Attitude toward SWD	–	Attitude toward SWD	Attitude toward SWD
Teacher Confidence	Teacher Confidence	Teacher Confidence	Teacher Confidence
Administration	Administration	Administration	Administration
Due to Covid	–	–	–
Material/Resource	Material/Resource	–	Material/Resource
Outside Factor	–	–	–
–	Implementation	–	Implementation
Student Result/Attitude	Student Result/Attitude	Student Result/Attitude	Student Result/Attitude
Team	Team	Team	Team
Time	Time	Time	Time
x	x	In-person	In-person
Virtual	Virtual	Virtual	x

Note: The Positive Program codes are colored green to indicate a positive result. The Negative Program column is colored dark orange to indicate a negative result. The nonprogram related columns are colored yellow for negative nonprogram related and blue for positive nonprogram related to indicate their secondary importance and the emerging nature of these themes in the study. A full codebook can be found in Appendix F.

Subcategories

The program themes had seven of the same subcategories for both of the negative and positive program codes: administration, materials, teacher confidence, time, virtual implementation, and team interactions. The nonprogram codes were similar to the program codes. “Self-reflection” and “self-efficacy” were added to the positive nonprogram theme, and “due to Covid” was added to the negative nonprogram theme. To address RQ 2, the following codes were used: “PosProg confidence,” “PosProg implementation,” “PosProg materials/resources,” “PosProg self-efficacy.” A full list of the codes is found in Appendix G. The counts of each code across all documents are found in Table 10. This table shows that the PosProg occurred most frequently with 38% coverage and 219 codes found across the documents. This result was followed by NegNonProg (29.57%) and PosNonProg (28.35%), which had similar representations. NegProg accounted for only 4% of the codes.

Table 10

Code Count and Percent Coverage by Theme

Document	August 2020	Implementation	Interviews	Action Plan	May 2021	Total
NegNonProg	5	88	68	1	8	170 *29.57%*
NegProg	0	10	10	0	3	23 *4.00%*
PosNonProg	21	80	52	3	7	163 *28.35%*
PosProg	3	106	82	14	14	219 *38.09%*

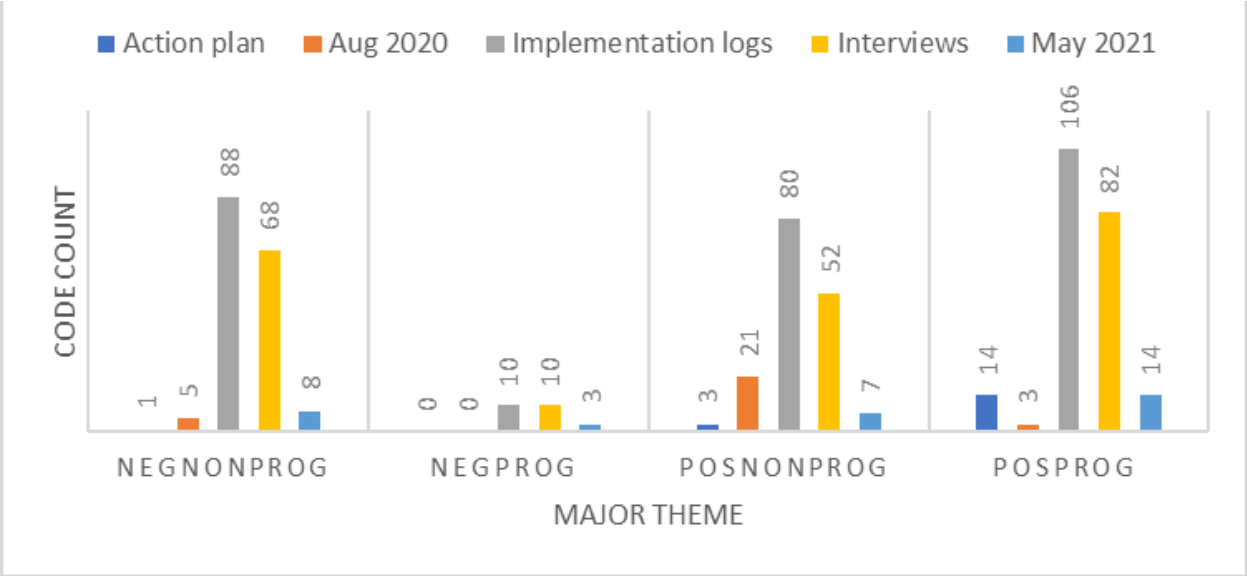
Note: Whole number = total count, Percent number = percent coverage.

Figure 6 illustrates that the implementation logs and interviews had the most codes and, therefore, offered the most qualitative data. This graph also shows that there are many more

PosProg codes than NegProg codes. This finding is emphasized by the similar counts of PosNonProg codes and NegNonProg codes. Participants were balanced in their overall attitudes for NegNonProg and PosNonProg. When it was specific to the ZBSE PD, PosProg attitudes had a much larger percentage (38.09%) than the NegProg (4%).

Figure 6

Influences on Teacher Confidence in Teaching STEM to SWD



Code Cooccurrence

To analyze if there was overlap between nonprogram codes and program codes, a code cooccurrence was run in the Atlas.ti analysis software. When running code cooccurrence in Atlas.ti, NegNonProg codes were compared to NegProg codes. There were 111 NegNonProg codes compared to 12 NegProg codes. There were overlaps between the NegNonProg “attitude toward SWD” and NegProg “implementation.” This result suggests that if a teacher had a negative attitude towards SWD then they may have negative implementation attitudes as well. Similarly, there was also overlap with NegNonProg “attitude toward SWD” and NegProg “materials/resources,” which indicates that having a negative attitude toward SWD may make using the provided materials and resources challenging. NegNonProg “virtual” and NegProg

“implementation” overlapped, suggesting that using the ZBSE PD virtually made the implementation of the program very difficult, because it was designed to be face-to-face.

When all of the NegNonProg and NegProg codes were compared to all the PosNonProg and PosProg codes, the cooccurrence table shows PosNonProg “in-person” and NegNonProg “due to Covid” had two overlaps. This result was replicated with two cooccurrences between NegNonProg “virtual” and PosNonProg “in person.” This result suggests that the ZBSE was not easily pivoted into virtual platforms. The teachers felt that the program needed to be in person. The cooccurrences were cross-references with quotations. The codes for NegNonProg “time,” PosProg “materials/resources,” and PosProg “team” all overlapped in Participant 1’s statement:

> I actually did a PD with my teaching staff, my colleagues, not my teachers, my colleagues, and they, I mean they, several of them got something out of it, and the one thing that they said was this is all real. It's all great. It's all perfect. Where's the time?

The NegNonProg “admin” and PosNonProg “team” codes had one overlap in Participant 1’s transcript: “I can move my behavior kids around because…I don't need an interpreter, and I usually have an aide to sit in the back of the room in case we start to see one ticking.”

The PosProg codes were compared within that category to find overlaps. The largest cooccurrences were found in the PosProg categories “implementation” and “materials/resources,” with 25 cooccurrences each. This result demonstrates the importance of the provided materials and resources to the success of the program's implementation. A teacher’s self-reflection was also a factor in positively implementing the program, as there were had nine cooccurrences between the two. Similarly, there were seven cooccurrences with self-reflection and PosProg materials.

Implementing the program face to face was found to be important, as seen in nine PosNonProg “in-person” cooccurrences with PosProg “implementation.” Self-reflection positively affected teacher use of the materials. Teachers who reflected on how to meet the needs of the

students found creative ways to use the materials. This was shown with the seven cooccurrences between the PosProg materials and PosNonProg student results/reactions. “The kids enjoy the modeling aspect of the activities” (Participant 2) is an example of what the students found positive in the program’s materials.

Table 11 shows that there were also six cooccurrences between UDL and PosProg “implementation,” which shows the importance of integrating these strategies into the positive implementation of the program.

Table 11

Cooccurrence Counts Between Positive Codes

Code 1	Code 2	Count
PosProg “implementation”	PosProg “Materials/resources”	25
PosNonProg “in-person”	PosProg “implementation”	9
Self-reflection	PosProg “implementation”	9
Self-reflection	PosProg “materials”	7
PosNonProg “student results/reactions”	PosProg “materials”	7
UDL	PosProg “implementation”	6

The largest number of negative cooccurrences was with the NegNonProg aspects of “virtual learning” with 17 cooccurrences. The NegNonProg “due to Covid” cooccurred with “team” and “time” as did the NegNonProg “virtual.” The other codes all cooccurred with NegNon Prog “virtual” as seen in Table 12.

Table 12

NegNonProg "virtual" cooccurrences

Code 1	Code 2	Count
NegNonProg "virtual"	NegNonProg "due to Covid"	2
NegNonProg "virtual"	NegNonProg "implementation"	2
NegNonProg "virtual"	Self-reflection	2
NegNonProg "virtual"	NegNonProg "time"	1
NegNonProg "virtual"	NegProg "implementation"	1
NegNonProg "virtual"	PosNonProg "in-person"	1

There was an overlap between NegNonProg "admin" and NegNonProg "team" quotes, which was summed up with "...they're not present because they get pulled out because of IEPs [individual education plans] or something…" (Participant 2).

When comparing negative and positive nonprogram codes about the program, there were 23 instances of NegProg codes and 219 PosProg codes. This result contrasts with the more even distribution of the NegNonProg and PosNonProg which tallied up to 170 negative and 163 positive codes. These results can be used to assess RQ 1 and RQ 3.

Mixed Methods Analysis of Documents

The following section analyzes each document with a mixed method approach to merge the data into a form that can be used to draw conclusions on the research questions. The quantitative data is presented and analyzed first followed by the qualitative. Then a mixed method comparison section is included for each document. Once all the data is presented and analyzed, the appropriate research question is addressed.

August 2020 Pre- and Postsurvey

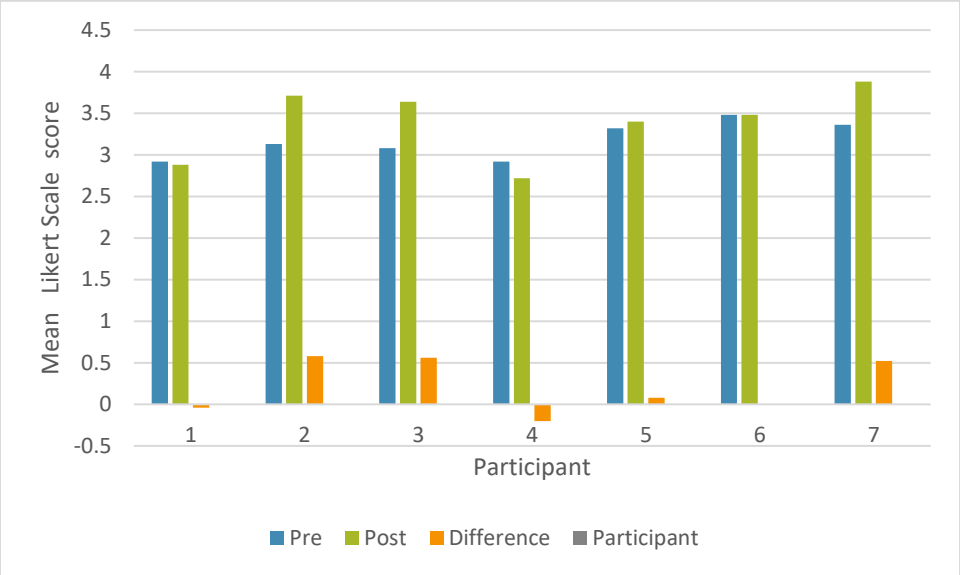
The pre- and post-surveys in August and May were almost identical and consisted of 25 Likert-scale statements and three open-ended questions. The survey was divided into five constructs that represented two or three of the statements in the survey. Construct 1 addressed special education training. Construct 2 asked about teachers' thoughts on SPED training. Construct 3 asked about teachers' beliefs about SWD, in general. Construct 4 asked about beliefs about SWD in terms of learning. Finally, Construct 4 asked about beliefs about SWD in terms of social aspects. Negatively asked questions were coded in reverse.

Quantitative Results

The quantitative results were mixed. This is likely related to the small sample size of seven. The August 2020 presurvey had 14 responses, while the postsurvey had only seven. This response rate resulted in less reliable comparisons between the pre and the post-surveys. The Likert scale used a 4-point scale: 4 = *Strong Agree*, 3 = *Agree*, 2 = *Disagree*, 1 = *Strongly Disagree*. Using the data from only the seven participants who completed both the pre- and post-surveys, the average difference in the mean was found to be .28 or 95%. The confidence interval that was run for the difference between the means of the pre- and post-surveys in August was 95% (0.17 and 0.40). The population mean (μ) thus fell between 0.17 and 0.40, which shows that the means were reliably different between the pre- and post-surveys in August 2020.

Figure 7

Mean Change in Likert Score by Participant



The Pearson Correlation Factor calculated between the individuals that completed both the pre- and post-surveys was .67. This finding represents a moderate positive correlation, which means there is a tendency for high *X* variable scores to go with high *Y* variable scores (and vice versa). The *p*-value was .10. The result was significant at $p < .10$. There was a moderate increase in positive correlation from the pre- to the postsurvey; however, as stated previously, there was a 50% drop in responses between the pre and the post, which lowers the reliability (Figure 7).

Qualitative Results

The open-ended questions of the August 2020 pre- and postsurvey introduced for the goals of the ZBSE. The first question asked about challenges the teachers faced with SWD. The second and third questions focused on teacher self-efficacy by asking how they could increase accessibility and inclusion in the classroom and what support they might need to do so. They were also asked why they wanted to take the PD.

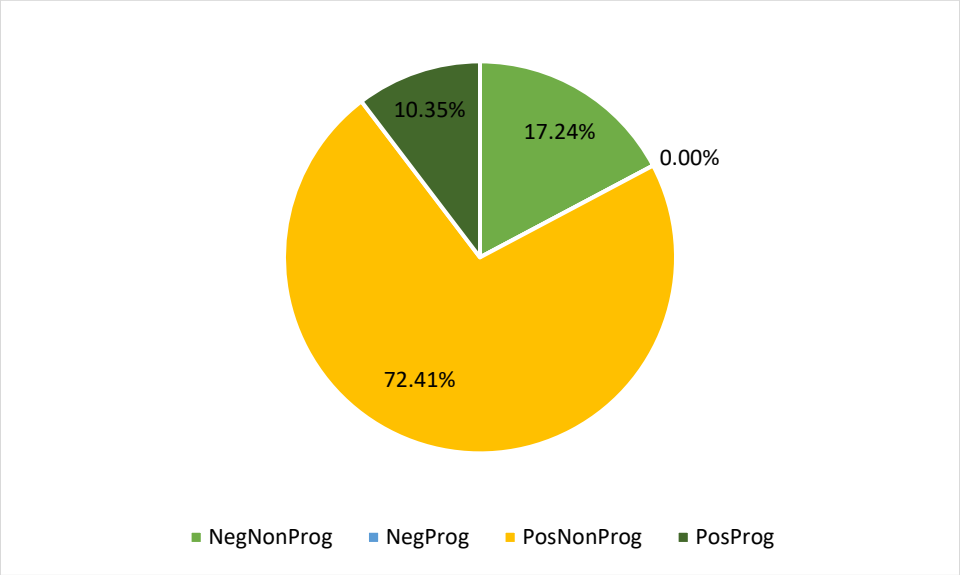
Teachers began the PD with enthusiasm; for example, “I am passionate about STEM education, and I want to instill that passion into the next generation,” (Participant 9). They were student focused throughout the survey and went beyond meeting the needs of SWD. Participant 1 included students with many underrepresented intersectionalities in STEM when he expressed a desire for “more resources for my students and breaking barriers for girls, students of color, and disabled students.” Participant 6 wanted to “... design exploration opportunities that will excite and engage my students.”

Teacher attitudes were positive toward learning along with their co-teachers, which was found to be an important aspect of the training. Participant 1 said, “Teachers should be trained in Special Needs situations, and as the disabilities are presented, each of the teachers should be retrained or taught best practices for the disability.” This response supports the literature review’s findings that collaborative PD with both teachers involved can positively affect teacher attitudes (Mutch-Jones et al., 2012). Participant 6 also felt that being trained with their co-teacher was important to influence positive student outcomes “I feel that my experience coteaching and working closely as a partner to meet the needs of all our students helped me grow as an educator.”

At this point of the training, there were zero codes of NegProg and 17.24% NegNonProg codes. The majority of the attitudes of the participants were positive, with general PosNonProg themes of 72.41% and PosProg attitudes of 10.35%. This result is illustrated in the circle graph in Figure 8, showing that teachers began the year with positive sentiments.

Figure 8

Percent of Main Themes in Aug 2020 Pre/Post -Survey



Mixed Methods Comparison

Combining the two data sets, it was found that teachers began the PD enthusiastically. At the time of the August 2020 PD, teachers did not know whether they would be in person or virtual. However, even with this uncertainty, they were engaged in the program and planning with their collaborative team. A telling sign was the number of participants in the presurvey (14) versus the postsurvey (7), which was indicative of the attrition that would occur throughout the school year. The quantitative data is combined with the qualitative findings in Table 15.

Table 13

August Pre- and Postsurvey Mixed Methods Results

Quantitative (Likert Scale results)	Qualitative		Mixed Methods Comparison
	Negative	Positive	
The confidence interval for the difference in means between the pre- and post-surveys showed a reliable change from the pre to the post. There was a moderate positive correlation from the pre- to post-surveys.	“I don’t have a problem teaching kids with disabilities. My issue is when the system fails them.”(Participant 3)	“I strive to design exploration opportunities that will excite and engage my students. I ask about their interests and try to include those interests in projects related to the curriculum.” (Participant 2)	This was the first step of this PD, and teachers came in with positive ideas about the program. At the end of the week, they did not have any negative comments about it. “Excited to work with these strategies proposed by UDL”

The August 2020 pre- and post-survey data were used to address RQ 1 and RQ 2 in Table 16. There was no data in this survey to address RQ3.

Table 14

How the Research Questions Were Addressed in the August 2020 Pre-and Post-survey

RQ1 How has the Zero Barriers in STEM PD impacted teacher attitudes towards meeting the needs of SWD in the classroom?	RQ2 How has the Zero Barriers in STEM PD affected teachers' implementation and understanding of the tenets of UDL?
Following the first PD in August 2020, teacher attitudes were positive towards meeting the needs of students with disabilities. There was a moderate positive correlation from the pre to the post-survey.	This first week of PD exposed some teachers to UDL for the first time "I will teach them based on their needs and learning plan" (Participant 4). Others already included the strategies in their classroom, " I provide visuals, checklists and modified directions for the students." (Participant 3)

Implementation logs

The implementation logs yielded the most quantitative and qualitative data. Some of the most robust information came from the analysis of these documents. The implementation logs were requested to be completed three times by each teacher throughout the school year following the August 2020 PD. During the school year, additional PD was offered but not required of the teachers. Some sessions addressed content-specific lessons, while others featured guest speakers that discussed UDL development and implementation.

A total of six logs were completed. Only one teacher completed two. Four other teachers completed one each, for a total of six data sets for the implementation logs. The Likert-scale questions on the survey ranged from 5 = *Strongly Agree*, 4 = *Agree*, 3 = *Neutral*, 2 = *Disagree*, and 1 = *Strongly Disagree*, for 22 questions. One question was asked in the negative. There

were nine yes-or-no statements concerning strategies and tools being implemented. The implementation logs ended with three open-ended questions.

Quantitative Results

The scores of the Likert-scale portion of the logs ranged from 1.33 to 4.67. The mean of the Likert-scale responses was 3.36, which is on the positive *Agree* side of *Neutral*. The standard deviation was .27, which suggests that there was little variability in the scores.

The implementation log Likert-scale questions had three main groups. One was student response, another focused on teacher attitudes toward the ZBSE program, and the last was about the practical application of the program. The means and standard deviations for the quantitative data of the implementation logs are ranked from highest to lowest for each group. As the mean gets closer to 5, there is a higher positive attitude or confidence in the category.

Teachers reported the highest positive student response as being comfortable with inclusive classes, which averaged 4.33 (Table 17). This was equal with student self-reflection, which was a tenet of UDL (RQ 2).

Table 15

Student Response to the Implementation of the Program

Statement	Students Comfort with Inclusive Classes	Student Self-Reflection	Students Care for Each Other	Students Involved in Class	Students Use Varied Formats	Students Don't Work Well Together
Mean	4.33	4.33	4.17	4.00	3.50	2.17
Standard Deviation	.52	.82	.75	.63	1.23	.75

Note: N=6

The teachers' confidence with the implementation of ZBSE PD is shown in Table 18. They had the most confidence in comfort with inclusive classes with an average of 4.67. The next three sentiments tied at 4.5: Comfort with UDL, Multiple Means of Representation, and Instructional Strategies for Vocabulary which all addressed RQ 2.

Table 16

Teacher Confidence with the Implementation of ZBSE

Statements	Comfort With Inclusive Classes	Comfort with UDL	Multiple Means of Representation	Instructional Strategies for Vocab	Uses UDL	Uses Collaborative Grouping	Confidence in the Curriculum
Mean	4.67	4.50	4.50	4.50	4.33	4.00	3.17
Standard Deviation	.52	.55	.55	.55	.52	.63	1.47

Note: N=6

The practical application of the program is ranked in Table 18. Teachers found that their colleagues were approachable and that they had access to assistive technology. The fact that the curriculum was used with a frequency of about half of the time (close to a mean of 3) supports the low mean of "confidence in the curriculum," which had a mean of 3.17 in Table 19. The materials may have been difficult to get (*M* = 3.00) because some teachers did not have access to their schools and materials.

Table 17

Practical Aspects of Teacher Implementation

Statements	Colleagues Approachable	Access to Assistive Tech	Goal Setting	Administration Is Approachable	Adequate Prep Time	Frequency of Curriculum Used	Materials Easy to Get
Mean	4.50	4.33	4.00	4.17	3.33	3.33	3.00
Standard Deviation	.55	.52	.63	.75	1.2	.82	.90

Note: N=6

The implementation logs also had a yes-or-no response section of the survey showing the usage of UDL tenets as presented in the program Table 20. The tenet used most frequently was using inclusive digital tools, with 100% of respondents using these. Sixty-seven percent of

the teachers developed and followed classroom norms. Fifty percent of the teachers used manipulatives, peer support, learning stations, and Total Physical Response. Total Physical Response is the use of movement while teaching vocabulary. The least used tenets were identity mapping and creating dictionaries.

Table 18

UDL or Strategies by Percent Usage

UDL Strategies	Total Count	Percent
Utilized inclusive digital tools (e.g. Kahoot, Bookshare, Raz-Kids, Google suite, QR code, etc.)	6	100
Classroom norms were developed and shared in class.	4	67
Students were offered different learning stations.	3	50
Manipulatives were used following the Concrete-Representational-Abstract method.	3	50
Arranged peer support for each pair of students.	3	50
Total Physical Response method was used.	3	50
Cooperative group strategies were used.	3	50
Identity mapping was implemented in instruction.	2	33
Students created dictionaries.	2	33
Average	3.22	53.67

Qualitative Results

The implementation logs were completed by five different teachers. One teacher completed two of the logs. They had been asked to complete three over 6 months. These documents were where teachers first began to express the difficulties outside of the program. Many focused on the virtual teaching difficulties. “Virtual has been difficult for many of my students” (Participant 3). Participant 4 said, “I have not been able to use cooperative groups digitally.” This was followed by restrictions placed on the virtual classes by the district: “Only one voice at a time can share online. I haven't been able to utilize break-out rooms,” which made implementation of some of the tenets impossible.

Some teachers remained positive by finding ways to engage students at home. Participant 5 was able to send materials home: “My students are doing labs at home through me creating boxes and distributing to them.” In fact, this teacher made “300 grades PK-5 boxes” for parents to pick up. Which she found “had a profound impact on my daily online teaching.” Participant 5 referenced ZBSE specifically as being useful in the virtual classroom:

> Using the Smithsonian class Zero Barriers, I was able to refer back to a variety of styles and learning methods. I was able to recall and use examples such as turning on Closed Captions while watching a video and making sure the lighting in my camera area was suitable to vision-impaired students. I wasn’t sure these things were making a difference, but it all came together when a student would remind me to turn on CC, or it’s too bright in my area.

Participant 3 integrated UDL tenets into virtual learning:

> In language arts, my students are building a sight dictionary in alphabetical order. During instruction, I use several programs that allow students to engage in learning activities by allowing them to respond with a picture, a written response, or a recorded response.

The last two implementation logs recorded in March and April 2021 demonstrated the teachers' fatigue caused by continuing to teach virtually. “We have continued to be virtual, and while I have tried to provide groupings, a bigger issue has been participation and engagement in class on a consistent basis” (Participant 4). This was also problematic for Participant 3: “It has been exceptionally challenging to engage and support students who are simply not logging into the classes.”

Mixed Methods Comparison

Teachers felt comfortable being honest in evaluating the program, tenets, and the real-world difficulties of teaching, in general, during the COVID-19 pandemic. A few teachers maintained a positive attitude throughout the year, while others struggled to teach due to the minimal participation they were experiencing. Table 21 shows that the quantitative and qualitative data reflect this.

Table 19

Implementation Log Mixed Methods Results

Quantitative (Likert Scale results)	Qualitative		Mixed Methods Comparison
The mean of the Likert Scale responses was 3.36, which is on the positive “agree” side of “neutral.” The binary analysis of UDL and application also yielded a similar result with a mean tenet usage of 3.22 or 54%	Negative Program Codes	Positive Program Codes	The teachers found that the program was rigorous but well presented. RQ2 was positively represented with the second positive program code quote. Still, the counts of UDL strategies revealed that they were only applied 54% of the time. Implementation was only slightly above average.
	“Inclusive classrooms, has had some difficulties because it’s hard to have ALL children feel accepted and supported within the classroom virtually.” (Participant 1) “Modification of curriculum with special education teacher to meet needs of students.” (Participant 5)	“I enjoyed the layout of the program. We have hands-on, visuals, multi ways for me to present and I didn't feel like I had to get to everything.” (Participant 3) “Using the Smithsonian class Zero Barriers, I was able to refer back to a variety of styles and learning methods.” (Participant 3)	

Table 22 shows how all the research questions were addressed through the implementation logos. Their rich data showed the difficulties of implementing new ideas while pivoting to online teaching and learning.

Table 20

How the Research Questions Were Addressed in the Implementation Logs

RQ1 How has the Zero Barriers in STEM PD impacted teacher attitudes towards meeting the needs of SWD in the classroom?	RQ2 How has the Zero Barriers in STEM PD affected teachers' implementation and understanding of the tenets of UDL?	RQ3 How can the Zero Barriers in STEM PD be improved for future iterations?
Teachers' attitudes had the most positively results from the students' self-reflection in the implementation logs. These were followed by positive answers in a collaborative grouping, student confidence in class, and access to technology. There was negative slant for instructional strategies for distractions, frequency of curriculum used, and comfort with an inclusive classroom.	The UDL Tenets showed negatively skewed results in the Implementation Logs. (Using varied formats, strategies for distractions, frequency of curriculum used, and confidence with an inclusive class, and confidence in the curriculum.	With so many issues related to online learning, teachers need additional resources for virtual classrooms should the need arise again to go back to virtual. They also did not apply many of the UDL tenets which may need to be re-emphasized in future groups.

May 2021 Pre- and Postsurvey

Following the implementation log collection, the final weekend PD was conducted in May 2021. This used a pre- and postsurvey that was very similar to the August 2020 pre- and post-surveys. They differed by omitting the following question: “Why do you want to take this PD, and what do you expect to learn?” There were only two respondents to the survey. They both

completed the pre- and postsurvey, but Participant 3 was ill on the 2nd day and did not complete the entire afternoon's activities.

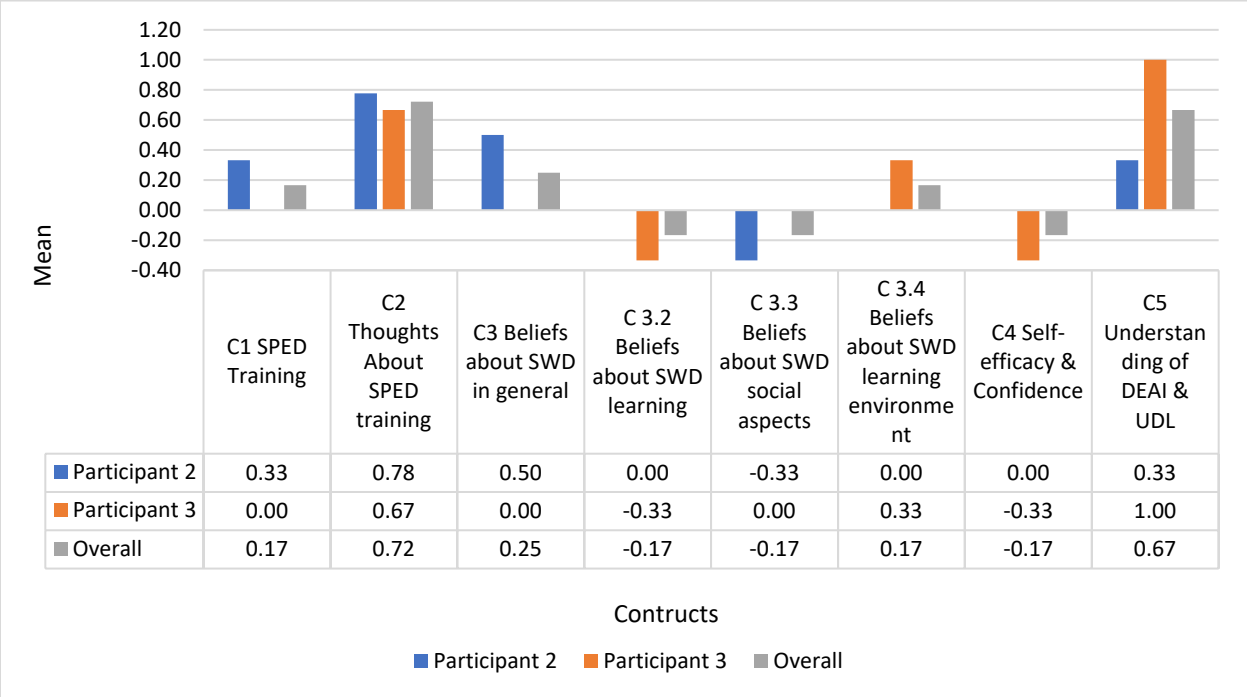
Quantitative

Running a one-way ANOVA repeated measures analysis was impossible due to the lack of participants who completed the May 2021 pre- and posttests ($N = 2$). Instead, the mean change in the responses was calculated and presented in Figure 9. Rather than include all of the 25 statements, the graph shows the mean by construct as designed by the SSEC. Each statement was aligned within one of the five constructs that were included in the August survey: "Special education training experience," "Thoughts about Special Ed training," and "Beliefs about students with special needs" which was subdivided into "Beliefs about students with disabilities in general," "Beliefs about students with disabilities in terms of learning," "Beliefs about students with disabilities in terms of social aspects," and "Beliefs about learning environment with special ed students."

Eleven statements had an increase in mean between the pre- and post-surveys in May 2021. Five sentiments decreased. The largest increases were in "using UDL," which corresponds with RQ 2. The two negatively asked questions indicated that teachers felt general ed teachers needed SPED training and were no longer were hindered by a lack of SPED training. A decrease in sentiment occurred with the following statements: "I can create space for SWD," "I become easily frustrated with SWD," "SWD have a negative impact on my class," and "The self-esteem of SWD is increased."

Figure 9

May 2021 Pre- and Post-Survey Change in Sentiment



Qualitative

The first open-ended question in the May 2021 post survey asked how they "taught students with disabilities in your class. What challenges did you face?" Keeping in mind that these questions were written before the pandemic, some teachers were back in the classroom or had adapted to teaching virtually at this point of the school year. Possibly for these reasons, the teachers did not mention virtual teaching as a challenge. Instead, Participant 2 said that students were "provided individualized support with 1:1 instruction" but that when meeting the needs of students with cognitive disabilities, "it's challenging to modify curriculum to meet their needs and check for understanding based on whole group assessments." Participant 3 spoke of the difficulties with allocating resources: "No additional supports in the space with too many variables to navigate." She recognized that "students who require additional supports may not

receive it because there are simply not enough human resources to assist." This response speaks to larger nonprogrammatic issues that face all educators.

Participant 2 again adopted a broader world view when answering the item, "How do you think you can increase accessibility and inclusion in your school?" She responded, "The school can increase accessibility and inclusion by providing resources, have parental meetings to monitor family engagement." This demonstrates an ability to see beyond oneself or one program as a cure-all for discrepancies in teaching STEM subjects to SWD. Taking an inclusive look at involving all stakeholders is an essential viewpoint in this large issue. Looking to partner with all who have an interest in improving SWD outcomes demonstrates this educator's ability to search for solutions beyond what is currently being offered.

On the last day, Participant 2 had concerns about aspects of education that were nonprogram related, such as,

> …the numbers and ratios of the students with disabilities. As a science teacher, I often do not get additional supports in the class like math or ELA, which makes it challenging to prioritize accessibility and inclusion to all the students. Those courses have smaller class sections and ratios.

These do not impact the evaluation of the ZBSE PD; however, they do create an opportunity to improve the program by addressing these issues upfront and having teachers work through recognizing what they can change versus what they cannot to maintain focus on strategies that are within their control. Teachers may easily lose sight of what is within their control, especially at the end of this particularly difficult school year that dealt with many changes for teachers and students alike.

Mixed Methods Comparison

A mixed-methods comparison is shown in Table 23. It provides the quantitative data from the participant but presents the qualitative data by positive and negative program codes. The comparison in the last column combines these two collection methods. Participant 2

showed an increased attitude in both the Likert-scale responses and her open-ended answers, which showed a positive outlook toward including more stakeholders to improve student learning in STEM. Participant 3 had a narrower view, which was evident in her decrease in Likert scores and her open-ended questions, which were focused on just her classroom. While this may create in increase in her ability to reach students in her room, Participant 2 showed the power of a more outward view and its effect on one's attitude overall in teaching SWD.

Table 21

May 2021 Pre-and Post-survey Results

Quantitative		Qualitative		Mixed-Methods Comparison
Participant 2	Participant 3	Negative Program Quotations	Positive Program Quotations	
There was an overall increase in the Likert scale question answers for this participant (.23). The largest increase was in Construct 2; Thoughts about SPED training (1.2 point change) and Construct 3: Beliefs about SWD in general (1.0 point change).	There was an overall decrease in Likert scale answers for this participant (.16). The largest decreases were in Construct 2 Thoughts about SPED training (-1.1) and Construct 5 (Understanding of DEAI and UDL (-1.0).	"I am concerned about the numbers and ratios of the students with disabilities. As a science teacher, I often do not get additional supports in the class like math or ELA, which makes it challenging to prioritize accessibility and inclusion to all the students" (Participant 2).	"Learning strategies to support students with all different types of needs" (Participant 3). "Special education teachers need training on general content to provide more support for the learner," (Participant 2).	With only two respondents on this final survey, it is best to only analyze the data for these specific teachers rather than make broad generalizations. There was a more positive change in Participant 2 than a negative change in Participant 3. Participant 3 could articulate the needs of gains of the program but also saw the challenges that are still present in the implementation depending on the support one receives at school.

The May 2021 pre- and post-surveys provided answers for all three research questions (Table 24), but the findings should only be applied to these specific teachers because only two participated in this PD and completed the survey.

Table 22

Research Questions and the May 2021 Pre-and Postsurvey

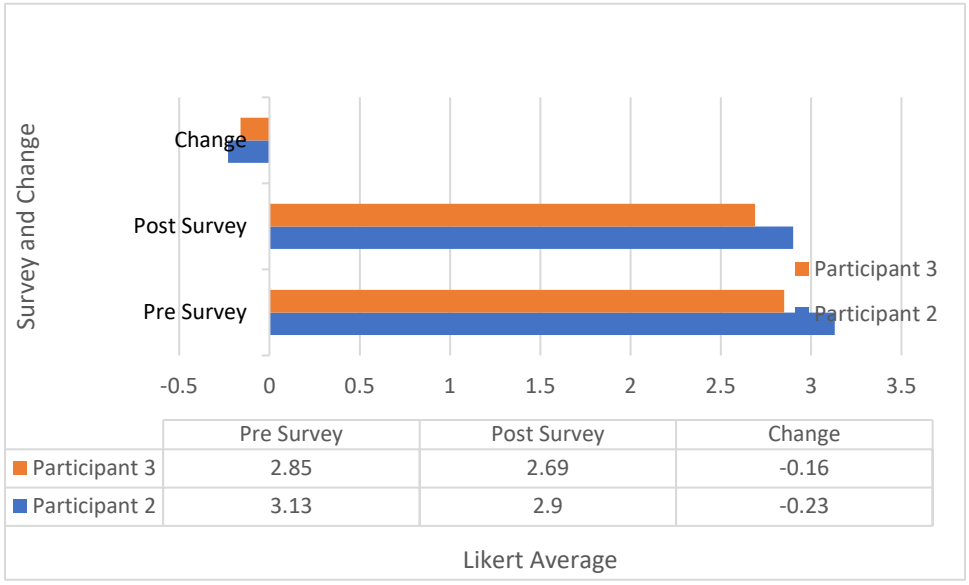
RQ1 How has the Zero Barriers in STEM PD impacted teacher attitudes towards meeting the needs of SWD in the classroom?	RQ2 How has the Zero Barriers in STEM PD affected teachers' implementation and understanding of the tenets of UDL?	RQ3 How can the Zero Barriers in STEM PD be improved for future iterations?
There were mixed results from the 2 participants. Participant 2 saw that many challenges were still present in meeting the needs of SWD. At the same time, she felt that she was ready to share the strategies with other teachers to continue pushing the initiative forward into more classrooms and schools.	Participant 3 had a decrease of 1 point in "Understanding DEAI and UDL" This is countered by Participant 2's increases on "thoughts about SPED training and beliefs about SWD in general." This shows that individuals will come away with varying skills from PDs in general depending on how open they are to learning the new strategies. This even speaks to the minutiae of how a participant is feeling at the time of the PD or the surveys. Participant 3 was ill throughout this weekend which most likely skewed her results into the negative.	The benefit of continuing to train teams of educators for the PD was evident in the comments "SPED teachers need training on general content" and the need for more support in the classroom.

An interesting finding was the change over the course of just two days on the May pre- and post-surveys for the two participants (Figure 10). As stated earlier, Participant 3 was not

feeling well and did not participate in the last day's afternoon activities. When comparing their Likert-scale data, both had lower scores on the last day than on the first day. Participant 2's postsurvey averaged higher than Participant 3's presurvey, indicating a more positive attitude coming into the weekend.

Figure 10

Change from Pre- to Post-Survey May 2021



	Pre Survey	Post Survey	Change
Participant 3	2.85	2.69	-0.16
Participant 2	3.13	2.9	-0.23

The May 2021 pre- and post-surveys used a mixed-method consisting of a Likert scale from *Strongly Disagree* to *Strongly Agree* (1-4) coupled with open-ended questions. Constructs 2 and 5 had the most negative change over time. This result may have been due to fatigue, as there were only five *Strongly* statements in the postsurvey but 14 in the presurvey. The fact that the teachers no longer felt "strongly" about anything also signifies that burnout may have been a factor. The lack of energy after a year of pandemic teaching could be a possible threat to the validity of the surveys.

Participant 2 also showed fatigue in her answer to the open-ended question in the Construct 2 postsurvey:

> I think it is important for all teachers to receive basic training to support students with disabilities, but it is definitely a collaborative effort. In my opinion, general education teachers are given a lot on their plate. While some strategies can be incorporated, it is important for there to be special education teachers written into a budget to support general education teachers as strategies are constantly changing. Not all strategies fit students, and having constant input or support from an additional teacher is always helpful to meeting the needs of all students.

This statement shows support for the team approach but also may be a result of this teacher being left to teach SWD with no collaborative support in her room.

Program Evaluation

The program evaluation was split into two parts that were given over the two days of the May 2021 PD program. It was written to evaluate the entire year-long PD program but also had specific questions that were just for the May 2021 PD session. Both days had a mix of quantitative and qualitative data collection. The first day evaluation had seven Likert-scale questions from 1-5: 1 = *Strongly Disagree*, 2 = *Disagree*, 3 = *Neutral*, 4 = *Agree*, and 5 = *Strongly Agree*. Day 1 focused on creating an identity map for participants to reconnect with team members. This activity was followed by participating in the “Change Game,” which guides teams through scenarios implementing systemic change in a school setting. There were three open-ended questions. Day two focused on a panel discussion on the benefits of inclusive STEM learning. Participants were then guided through creating a team action plan to implement for the 2021-2022 school year. They were then given guided time to work on this with facilitators of the program as well as with members of their team.

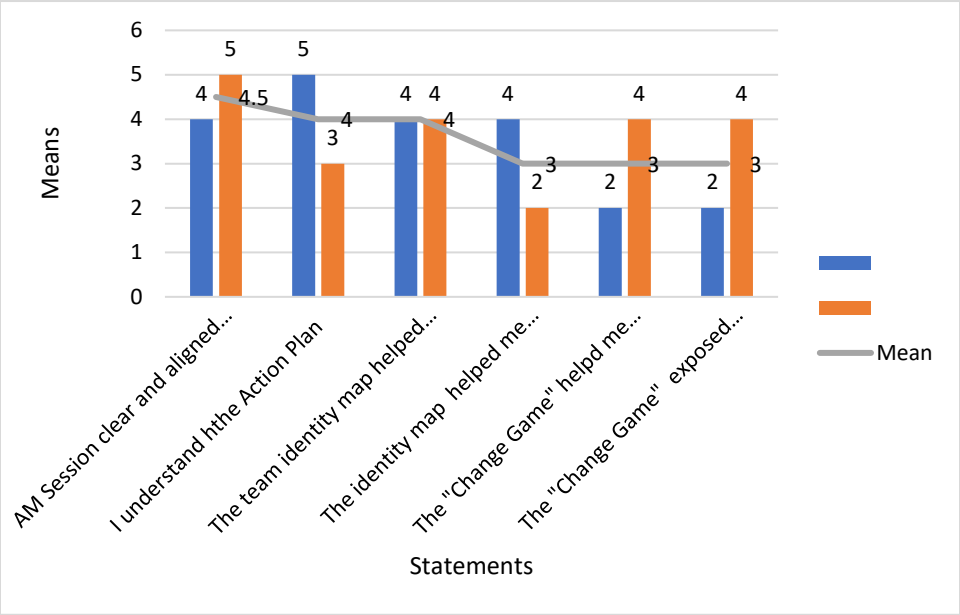
Quantitative

The overall Likert-scale mean for the first day of the May 2021 PD was 3.58, which fell between *Not Sure* and *Agree* but leaned slightly more toward *Agree*. The Change Game and

identity mapping reviews brought down the average, with scores of 2 for different participants. This result is supported by the open-ended answers that complained about the length of the directions of the Change Game. The Day 1 Program Evaluation means are graphed in Figure 11.

Figure 11

Day 1 Program Evaluation



The 2nd day of the evaluation focused on more general questions that covered the entire PD, as seen in Figure 12. There were 33 Likert-scale questions, scaled from 1 to 5 as in Day 1. There were five open-ended questions. An example of a general Likert-scale question was, “How did you feel about using the learning management system Moodle, the sessions, presenters, and general thoughts applied to the entire school year?” Topics specific to the May 2021 PD were teamwork time, think tank, and keynote speakers. These were rated the highest on the survey.

The Day 2 means were higher than Day 1, with an overall mean Likert-scale score of 4.02, which equates to the positive attitude *Agree*. However, one participant did not participate

in the Team Worktime, Think Tank, or the Messaging & Keynote activities due to illness and entered “not sure” for these afternoon activities. For this reason, the means are not presented by overall statement in Figure 12.

Figure 12

Day 2 Evaluation Means by Participant

Qualitative

There was only one open-ended question on the 1st day of evaluation: “What ideas or concepts did you take away or will you implement from today's session.” Participant 3 focused on personal reflection and self-efficacy:

> One of the underlying variables to supporting student access and addressing student needs requires self-reflecting on the teachers (myself) to recognize where I am coming from, my strengths, weaknesses and what I bring to the table to support my students.

Participant 1 learned the importance of teamwork when trying to effect change: “How important communication is when trying to implement change. Action plan template - Narrowing down my scope for change.” This was the final PD in a year-long program, so it is significant that Participant 1 had turned her sights to including others to promote change. Participant 3

could see the importance of encouraging others to reflect on where they could make improvements in supporting students. Both are important, but Participant 1 shows they had moved beyond their influence and sought to influence others, broadening their impact.

Day 2 had four open-ended questions. The first was, “How do you expect your school to benefit from your work at the Summit?” Participant 3 was concise in stating that they hoped to “Improve science literacy.” Participant 1 again took a larger scope of what was needed: “My school can benefit from the open discussions of the need for training and professional development for UDL strategies and considerations for supporting all learners.” This statement shows a desire to make a larger impact on student outcomes by sharing UDL strategies learned.

The second open-ended question was, “What questions do you have about the work today? What programmatic or logistical suggestions do you have for improving this virtual summit?” Neither participant had any questions about the program. However, Participant 1 had suggestions about the Change Game when answering. She responded, “The logistics and directions for the [Change] game were overwhelming and took a long time to explain. It was hard to capture my attention and provide clarity on the directions for the game.” The Change Game was designed for teams of teachers to work through together as a model for effecting change in a community. It was challenging when there were only a few participants and was less impactful when not working with a school team to plan a way to create change in a school. There was also an obvious struggle to get teachers to attend, which both participants addressed. “Being virtual made it a huge challenge to attend the summit and get commitment from my team” (Participant 3). “Consider having sessions during the week and streamline asynchronous activities (Participant 1).

Both participants found that the PD helped them find their voice in creating change in their school by improving their communication skills and creating effective Action Plans:

“Opening dialogue with my colleagues” (Participant 3). “Writing an effective Action Plan and creating buy-in” (Participant 1).

Similar to findings throughout the PD, the teachers had many positive statements about Question 3, “Please comment on the most useful part of this experience.” Some of it was specific: “Understanding the integral pieces of the Action Plan” (Participant 3). Participant 1 focused on the many how-tos: “How to write a clear and concise problem statement. How to identify activities, owners, and resources. How to create interest buy-in.” A more general accolade was given by Participant 3, who finished with an appreciation for the presenters and their resources, “I appreciated the resource and the enthusiasm from all of the speakers.”

Mixed Methods Comparison

The qualitative and quantitative data support each other. Participant 2 had an increase in attitude toward teaching STEM to SWD, as shown by her increased Likert scale results. She also had a world view of implementing change school-wide to increase STEM access for SWD. This view may have been because of administrative support. This participant was most invested in the program and completed the most aspects throughout the year (see Table 8 in the attrition section of Chapter 4). Combining the qualitative and quantitative results of the evaluation using mixed methods analysis is found in Table 25.

Table 23
Comparison Chart of Program Evaluation

Quantitative (Likert Scale results)		Qualitative		Mixed Methods Comparison
Negative	Positive	Negative Program	Positive Program	The results of both the quantitative and qualitative evaluations showed positive attitudes towards the program.
The lowest scores of 3 were about the Change Game and the learning management system "Moodle" which had a mean of 4.	Both Teamwork and Think Tank had an average of 5, strongly agree.	(5 total codes) "Being virtual made it a huge challenge to attend the summit and get commitment from my team." For the program, one negative code was "The logistics and directions for the game were overwhelming…"	(178 total codes) "One of the underlying variables to supporting student access and addressing student needs requires self-reflecting on the teachers (myself) to recognize where I am coming from, my strengths, weaknesses and what I bring to the table to support my students."	There was an overwhelmingly positive response to the program both in sentiment and according to the Likert scale. There were no scores below "neutral," and the negative codes were mainly about situations beyond the scope of the PD.

The program evaluation addressed the three research questions with the mixed method findings. Teachers gave suggestions for improving the program, including less asynchronous work, classes during the week, and going back to in-person. These findings are supported by research in the literature review (Affouneh et al., 2020). Teachers stated that being given time for self-reflection had positively affected their attitude toward teaching STEM to SWD. The research questions and examples are provided in Table 26.

Table 24

Research Questions and the Program Evaluation

RQ1 How has the Zero Barriers in STEM PD impacted teacher attitudes towards meeting the needs of SWD in the classroom?	RQ2 How has the Zero Barriers in STEM PD affected teachers' implementation and understanding of the tenets of UDL?	RQ3 How can the Zero Barriers in STEM PD be improved for future iterations?
The Likert scale showed that teachers felt neutral about gaining confidence after using the identity map tool. The open-ended statement supports this. "One of the underlying variables to supporting student access and addressing student needs requires self-reflecting on the teachers (myself) to recognize where I am coming from, my strengths, weaknesses and what I bring to the table to support my students." (Participant 3)	The content sessions covering UDL tenets scored high on the evaluation. "My school can benefit from the open discussions of the need for training and professional development for UDL strategies and considerations for supporting all learners." (Participant 2) This supports a positive outcome for this research question.	"Consider having sessions during the week and streamline asynchronous activities." "Being virtual made it a huge challenge to attend the summit and get commitment from my team. Many teachers recognize a problem but struggle to follow through or go through the steps for trainings." "In the future, it is recommended to have paid time during the regular week to attend training such as these with the districts providing substitutes so teachers wouldn't feel it was an extra unpaid burden."

Action Plan

How to design and implement an action plan was the second day's focus of the May 2021 ZBSE PD. The teams were tasked with creating an action plan to implement a goal to apply what they learned at the ZBSE PD beyond their classroom. The action plan template was based on a logic model that had space for the problem statement and goals and columns for activities to support those goals. The template also had space for owners, resources, and expected outcomes. Only one action plan was turned in to be examined. There was no quantitative data on this document, so there will not be a mixed-methods analysis, only qualitative.

Qualitative

This team (Participant 2 and a district administrator) chose to focus on science literacy. Their main goal was as follows: "In a school year, elementary school students will read science literature two times a week through multiple access points at their reading level through inclusive and accessible strategies." The three proposed strategies to meet this goal were based on UDL's accessibility practices:

1. Text to speech
2. Modification of the text
3. Supports to ensure students can access science reading

The activities on the action plan addressed what administrators needed to do to support the plan, "Administrators will allocate planning time in the teacher schedule." The instructional staff planned to complete the bulk of the work by creating the following:

1. Reading Logs template
2. Rubric for word book dictionaries.
3. Video and worksheets
4. Modified curriculum and assessments

The action plan also had ways for staff to meet the goals: “IT and Media Dept will ensure students have technology software and access on student devices to use Carolina Science Lit, Rewordify.com, PlayPosit, Nearpod, Youtube.”

The action plan included the needed resources, which included increasing instructional time by preparing lessons ahead of time to incorporate “more UDL for learning.” Another resource noted was an increased budget for office supplies. They also requested easy access to the reading levels of students with cognitive disabilities to prepare adequately modified lessons.

Under “expected outcomes,” the goals were divided into short term (less than 6 months) and long term, defined as longer than 6 months. In the short term, teachers would use the “reading Plus Intervention resources twice a week. The teachers would “guide the intervention, individual support, and vocabulary skills” in the classroom. They also proposed to meet with the SPED coordinator to “determine which students need text to speech and tier 3 reading intervention.” They hoped to see an increase of 20-30% in reading comprehension in the long term.

This document did not have as much data to analyze as some other documents. Still, it addressed RQ 2. Following the year-long PD, teachers were planning to share their knowledge of UDL practices with other educators and staff members to build support for teaching STEM to SWD (see Table 27).

Table 25

ZBSE Participant Action Plan

Qualitative		Research Questions
Negative Program codes	Positive Program Codes	Evidence that RQ 2 is answered positively is found in the proposed activities that implemented UDL tenets. The educators planned to use UDL practices like “text to speech, modification of test and supports to ensure students can access science reading.”
The only negative program statements coded were the problems the group was trying to address. “Students with cognitive disabilities have difficulties reading scientific literature.”	This document had many PosProg Team codes, which showed a collaborative attitude towards interventions for the students. There was mention of using the “Carolina Science Lit, " provided by the SSEC for this program.	

Interviews

The interviews collected qualitative data only, so no mixed methods analysis is included, but any research questions addressed in the interviews are discussed. The amount of PD engagement by the interview participants was an important consideration in this section of the study. An abbreviated version of the table in the Participant Attrition section is included in Table 28.

Table 26

Abbreviated Participation Table

Partic-ipant Num-ber	August 2020 Pre-survey	August 2020 Post-survey	May 2021 Pre & Post	Imp Log 1	Imp Log 2	Imp Log 3	Action Plan	Prog Eval	Final Intervie w
1	3.14	3.71	-	4.00	-	-	-	-	Mixed
2	2.92	2.88	.20	3.36	-	3.73	Positive	4.81	Mixed
3	2.92	2.72	.17	-	4.00	-		3.65	-

Note: Averages 3.10 and above are coded green to indicate positive responses. Averages between 2.90 and 3.10 are a neutral yellow and averages 2.89 and below are coded red to reflect negativity.

The participants' identifying numbers have remained the same throughout the research study. As can be seen, Participant 2 has had a voice in each document analysis. Although the interview was half as long as Participant 1's, her sentiments have been adequately captured in this study. Participant 1 did not complete any implementation logs, nor did he attend the May 2021 PD, which was a source of three analyzed documents. Participant 3 also participated in each of the documents but did not return requests for the interview. With this knowledge, it can be postulated that a balanced view of the program will be reached, as there was one participant who was positively engaged and one interviewee who was less invested in the program and attended the final weekend PD.

The interviews with Participants 1 and 2 were conducted in March 2022, 10 months after the concluding May 2021 PD. Participant 1's transcript was 41 pages long. Participant 2's transcript was 25 pages long. The interview with Participant 1 lasted about 50 minutes. The interview with Participant 2 was about 30 minutes long. The participants were comfortable sharing both positive and negative aspects of teaching STEM to SWD.

The interview questions stemmed from each of the research questions. Research question Responses to RQ1 are found in Table 29.

Table 27

Responses to Research Question 1

RQ 1 How has the Zero Barriers in STEM PD impacted teacher attitudes towards meeting the needs of SWD in the classroom?	Participant 1	Participant 2
Question 1 How have your beliefs about teaching STEM to SWD in general changed since the end of the PD?	I think you're refreshed on things that we need to step back and look at to provide it.	"It was encouraging to believe that students with disabilities are capable of doing STEM."
Question 2 How has in-person teaching affected these beliefs and attitudes?	I actually implemented zero barriers a lot more efficiently	"In-person has increased them" (in regards to the attitudes and beliefs about SWD learning STEM)
Question 3 What lessons from the PD influenced your ability to teach STEM to students with disabilities?	We were able to build things and take it for the build the ramps in the barrier program and so I think I was able to implement it big time	My STEM class uses the STEM aspects of their energy and transfer unit"

Research Question 2 showed that both participants felt better prepared to teach SWD after the program as summarized in Table 30.

Table 28

Responses to Research Question 2

RQ 2 “How has the Zero Barriers in STEM PD affected teachers’ implementation and understanding of the tenets in UDL.”	Participant 1	Participant 2
Question 4 Did you feel adequately prepared to teach STEM to SWD?	“So no, I'm not prepared in [my district]. I thought I was prepared and I know I was prepared in [my previous district].”	“Afterwards? Yes. Initially, No.”
Question 5 Were there any specific lessons or techniques that you were able to apply to your teaching?	“Y'all had a race car one was really cool. I took that a little bit further and then kind of added on to it.”	“We have the text to speech. They love that. Most of the UDL strategies work well.”

The final research question was, “How can the Zero Barriers in STEM PD be improved for future iterations?” which was probed by asking questions related to supports and barriers to implementing the strategies and acknowledged the unusually difficult year the ZBSE PD was piloted. Responses are found in Table 31.

Table 29

Responses to Research Question 3

RQ 3 “How can the Zero Barriers in STEM PD be improved for future iterations?”	Participant 1	Participant 2
What barriers or challenges did you experience while teaching the curriculum?	“I actually did a PD with my teaching staff, my colleagues, not my teachers, my colleagues, and they, I mean they several of them got something out of it and the one thing that they said was this is all real. It's all great. It's all perfect. Where's the time?”	“My challenge is that the collaborative teacher is not science-based. So, when I actually teach a unit with them, they were like, “Oh, wow, this is all foreign to me” So it's like I'm teaching them as well.”
Were these related to Covid?	[Yes] “They're killing us right now, with everything that we're doing. And I know we're trying to make up time but you know, taking time away from us.”	(Not related to covid)
How has the support from colleagues impacted your ability to implement the strategies?	“I work with a phenomenal, phenomenal group of teachers who really support special needs. The one thing they said is if we had more time, we could do so much more. It seems like we had more time years ago, but there was no emphasis on this. Now there's no time, but there's more emphasis.”	“Not really, because the colleagues at the middle school probably aren't aware of the program. My initiative was, oh, I wanted this fabulous program and got all these things. I don't want to just leave it to elementary school, I’ll take it with me to utilize it.”

How has your prep time or effort changed as a result of the PD?	“[It’s easier], Totally. When I do Zero Barriers right there I don't have to go and find it myself. I don't have to go to the store or get it reordered or whatever. So that's what I like, the refill kit.”	“I think my prep time will probably be considered less prep time. But I don't think it's due to the actual program. It's just the allocation of time that you're given.”

Examples of the main themes were compiled in Table 32 with sample interview quotations from each participant. The negative sentiments are related to outside factors due to implementing the program virtually or due to pandemic teaching in general.

Table 30

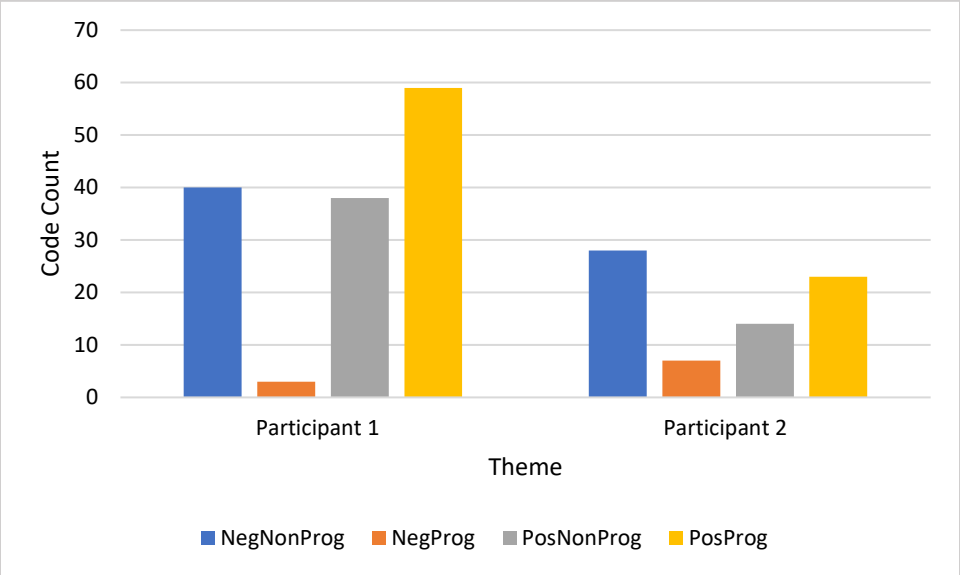
Interview Sample Quotes by Major Theme

Negative Program Codes	Positive Program Codes	Negative Nonprogram	Positive Nonprogram
“I lost my online kids,” Participant 1 “We used the big one [textbook]. It became more awkward for the kids. They were too big and I guess that could be because we were in COVID.” Participant 1 “It does still require a lot of modifications” Participant 2	“Most of the UDL strategies work well,” Participant 2 “It was already set up for students with disabilities because it was hands-on” Participant 1	“It would've been more effective if students were in-person to apply the STEM component to build and apply understanding,” Participant 1 “My challenge is and is probably the most, is that the collaborative teacher is not science-based… So, it's like I'm teaching them as well.” Participant 2	“So usually with students with disabilities, that tactile learning is a little bit more exciting than just me going over only notes and concepts.” Participant 2 “I really think in-person is the way.” Participant 1

Participant 1 had 40 negatively coded (NegNonProg) comments unrelated to the ZBSE PD. An example was, “We were being bombarded with new technology.” The NegNonProg theme had the most comments from Participant 2: “They started taking our collaborative teachers out of our classrooms, so then I felt like I needed to pick up the pace with what I needed to do.” The two participant’s counts within each major theme are represented in Figure 13. Participant 1 had twice as many codes applied to the transcript with 140 compared to Participant 2’s 72 codes.

Figure 13

A Comparison of Codes by Theme and Participant



Another way to analyze the data is by participant as seen in Table 33. Each document was looked at for overall positive or negative attitudes about the program based on Participants 1, 2, and 3 because they contributed the most data to the case study, as seen in Table 33. For the August and May Surveys, the Likert scale was from 1 to 4. The midpoint would be 2.5, so any numbers above were coded green to reflect a positive attitude. The implementation logs had a Likert scale of 1-5, so the midpoint is 3. Anything 3 and above is coded green to reflect

this positive attitude. The program evaluation also used a Likert scale of 1-5, so anything above 3 is coded green for positive. The chart definitively shows that there were overall positive attitudes in teacher responses to the ZBSE PD.

Table 31

Participant Quantitative Data by Document

Part Number	Aug 2020 Pre 1-4	Aug 2020 Post 1-4	May 2021 Pre 1-4	May 2021 Post 1-4	Imp Log 1 1-5	Imp Log 2 1-5	Imp Log 3 1-5	Prog Eval 1-5
1	3.14	3.71	-	-	-	-	3.95	-
2	2.92	2.88	3	2.84	3.36	-	3.73	4.81
3	2.92	2.72	3	2.8	-	4	-	3.65

Reliability

I scored the interviews and then they were scored by an independent evaluator. This accounted for 20% of the qualitative data. The second coder was a fellow graduate student in with a focus on special education. The coder was unfamiliar with the ZBSE program but had attended the prospectus hearing and was presumed to have a basic understanding of the PD. Fidelity was ensured by providing the second coder with the codebook and definitions. Interrater reliability was collected on 100% of the interview sessions. This represented over 50% of the qualitative data coded. Reliability was calculated through point-by-point agreement (agreements/agreements + disagreements × 100; see Kazdin, 2011) with an expectation of 74% or better, which is considered moderately acceptable. Coder agreement and percent agreement are listed in Table 34.

Table 32

Coder Agreement by Count

Category	Counts that Agree	Counts that Disagree	Percent agreement
NegNonProg	68	7	89.71
NegProg	10	6	62.5
PosNonProg	52	22	70.27
PosProg	82	23	71.95
Total	212	58	73.60

One issue was that the second coder used the web-based version of Atlas.ti, which had to be imported into the desktop version. This resulted in having to hand-calculate the interrater agreement rather than use Atlas. Other threats to validity occurred because some of the codes applied by the second coder did not match the description provided in the codebook. For example, the code “NegProg Materials/Resources” was attributed to the quote, “Not really, because the colleagues at the middle school probably aren't aware of the program.” The definition provided was, “This is not due to Zero Barriers but to the other resources being thrown at the teachers.” This was coded incorrectly and should have been coded “NegNonProg “outside factor” due to the fact that the other teachers weren’t aware of the program because the participant had moved to a new school. Another threat to validity is that the second coder coded both the researcher’s statements and those of the participants.

Missing Data

The analysis of the documents showed that, on occasion, open-ended questions were not answered as part of a mixed-methods document, which may have occurred because they tended to come after the Likert-scale questions. Participants may have experienced fatigue at that point. On the August 2020 pre- and postsurvey, one respondent omitted the open-ended Question 27, “How do you think you can increase accessibility and inclusion in your class?”

Another participant skipped that question and three additional open-ended questions: “Please describe how you teach students with disabilities in your class. What challenges do you face?” “Why do you want to take this PD, and what do you expect to learn?” “What resources do you think you need to support students with disabilities in your lesson?”

One respondent did not answer any of the open-ended questions on the implementation log. On the first day of the May 2021 program evaluation, neither of the two participants answered, “What questions do you have about the work today?” One of the participants did not answer the following questions, “What programmatic or logistical suggestions do you have for improving this virtual summit?” These responses may have been omitted because the work was well explained to the participants, and they had no suggestions.

The lack of full participation in the data collection further exacerbated the lack of respondents. Because only two participants completed the May postsurvey, the fact that one teacher did not answer six of the 25 postsurvey questions creates questionable validity to those results. It was unknown whether they were excluded because the participant's perception was that everything was fine or if they were too fatigued to give negative feedback. The implementation logs had the most robust data, so the omission of the open-ended questions was not as significant. Overall, the data collected across the six documents were significant enough to answer the research questions, but further analysis of new data as the program continues will be more helpful to the program facilitators.

Chapter 5 Conclusion

This mixed-methods case study aimed to identify changes in teacher confidence and attitudes toward teaching STEM to students with disabilities (SWD) following their participation in the Zero Barriers in STEM Education Professional Development. (ZBSE PD). The interview protocols and research questions were developed after the initial analysis of the teachers' pre-surveys in August 2020 and post-surveys in May 2021. The analyses of the surveys, action plans, implementation logs, program evaluations, and interviews were used as a case study to determine if the program positively or negatively affected teacher confidence and attitudes in teaching STEM to SWD. This chapter will analyze how the literature review affected the understanding of the findings. The methodology will be examined for successful implementation. The discussion of outside factors follows the summary of the and leads to the implications of the project. Finally, recommendations for further research are included before a final conclusion.

The ZBSE PD was a pilot study that was supposed to be conducted in person with the collaborative teams and administrators from a Mid-Atlantic school district. The Smithsonian Science Education Center (SSEC) developed a program that trained teachers on UDL practices in STEM and the Smithsonian Science for the Classroom curriculum. Further PD was to be offered throughout the school year to reinforce content and UDL strategies. The SSEC created a program that included many research-driven supports for the successful implementation of a PD program, as shown in Table 36. The only one they could not include was the flexible time and location of the PD. The major change to the program was that it had to be delivered virtually due to the pandemic.

Table 33

Barriers and Supports for STEM PD

Effect on Teacher Confidence	Positive (Support)	Negative (Barriers)	ZBSE PD
Equipment funding (Hanley et al., 2020)	x	-	x
Planning Time (Johnson, 2011; Affouneh et al., 2020; Yang et al., 2020)	x	-	x
Movement of teachers through grade levels (Adamson et al., 2013)	-	x	x
Overall, Teacher Attrition (Adamson et al., 2013; Johnson, 2011; Yang et al., 2020)	-	x	x
Increased accountability on standardized tests (Johnson, 2011)	-	x	-
Mandated PD (Affouneh et al., 2020)	-	x	-
PD during contract hours (Affouneh et al., 2020)	x	-	x
Teachers with some previous skills (Affouneh et al., 2020)	x	-	x
Administrative support of the PD (Affouneh et al., 2020; Yang et al., 2020)	x	-	x
Flexible time and location (Affouneh et al., 2020)	x	-	-
Additional training time (Yang et al., 2020)	x	-	x

Unfortunately, the specter of COVID-19 loomed over the entire pilot program. The first adjustment due to the pandemic was that the PD was switched to virtual, starting with the initial PD week in August 2020. At that time, teachers were unsure if they would be able to teach in

person or if they were going to remain virtual in the new school year. For some, their materials remained in their schools, inaccessible to them. Others were able to work with administrators to package the materials individually so parents could pick up kits to use at home. Hanley et al. (2020) found that funding for equipment positively supported the implementation of PD; therefore, there may have been a negative impact on teacher attitudes about the program for the teachers who did not have access to their materials.

There were two additional barriers that were beyond the control of the SSEC: teacher attrition and teacher grade movement. Participant 2 began as an eighth-grade science teacher in the program but moved to another school the next year, 2021-2022. In her interview, she shared that going to another school without her team of ZBSE teachers impeded their ability to implement their action plan. Her response to the question, “Do you know if they implemented any of it at the school you left?” was as follows: “I left with an action plan. But I doubt I they implemented it. It’s all new administrators, all new teachers. So, it got lost.” Participant 3 was also a middle school science teacher. She did not participate in the final interview, and it is unclear if she remained at her school.

It would be expected that teacher attitudes toward teaching STEM to SWD would increase throughout the school year as teachers applied the strategies from the PD in the classroom. However, the results were significantly affected by program attrition. This was likely due to teaching during COVID-19 (Marshall et al., 2020). Teachers were asked to continue teaching virtually to students who had missed much of the last quarter of the previous school year. Because of this setback, the previous school year’s missed curriculum was being squeezed into the current year. This put science on the backburner while teachers caught students up on reading and math concepts. Teachers felt overwhelmed by the number of times collaborative teachers could not support them in the science classroom due to staffing issues exacerbated by COVID and the focus on math and language arts. “As a science teacher, I often do not get additional supports in the class like math or ELA [English language arts]” (Participant

3). With these barriers, supports, and unexpected existential crises, the findings of this research study were mixed.

Summary of Findings

The data collected met the needs of this case study by providing varied data, both qualitative and quantitative. The small number of participants made generalizations difficult, but the data sets did support each participant's attitude throughout the PD. The largest conclusion is that there were few negative feelings toward the program across all documents and the participants. The three participants who engaged with the entire program had their ups and downs in attitude and confidence in teaching STEM to SWD. This could be due to personality and circumstances like school placement and teammates. Despite all the barriers to fully implementing the program, it can be seen as a success since there were so few negative comments overall. It will be worth following the next cohort to gather more data and make a more accurate program assessment.

Another major finding was that there were great difficulties faced by the teachers as they attempted to implement the program while also dealing with the upheaval caused by the COVID-19 pandemic. The teachers who attended and participated the most were found to be positive in both the program and nonprogram themes, as the year progressed (Table 35). The teachers with the highest participation levels came from three different schools in three different grade levels and served in three different positions. The three most engaged participants were compared using mixed methods to evaluate their general attitude, as it changed from the August 2020 PD to the May 2021 PD. Table 35 uses red to indicate below-average quantitative scores and converging qualitative statements. Green indicates above average, and yellow showing an average score of +/- .3.

Table 34

Attitude Change Over Time by Document

Partici-pant	Aug Pre 2020	Aug Post 2020	Imp Log 1	Imp Log 2	Imp Log 3	May Pre 2021	May Post 2021	Prog Eval	Inter-view
1	Neg-ative	Positive	-	-	Positive	-	-	-	Positive
2	Neg-ative	Neg-ative	Neg-ative	-	Positive	Positive	Neutral	Positive	Positive
3	Neg-ative	Neg-ative	-	Positive	-	Positive	Neutral	Positive	-

Some documents were robust enough to answer all three research questions, while others could only be used to answer one or two. However, taken as a whole, enough data were collected to draw conclusions about the questions. When comparing only the negative and positive program codes, there were two “negative program” codes for “virtual” implementation and 99 “positive program” codes. This result indicates an overall positive program experience except when applying the program virtually. This discussion will address each research question and then discuss the findings. Finally, the practical and theoretical implications of the study will be addressed.

Research Question 1: How has the Zero Barriers in STEM PD impacted teacher attitudes toward meeting the needs of SWD in the classroom?

The teachers' attitudes toward meeting the needs of SWD increased throughout the program until the last PD session in May. There was a reliable increase between the August 2020 pre- and post-surveys. Participant 1 felt that both the SPED and content teachers should be trained to best meet the needs of SWD. There were zero negative program codes at this

point of the program. Teachers seemed excited to have new materials and curricula in their toolkit to serve their students.

The implementation logs also showed a strong positive attitude toward the program's application. Seventy-two percent of the statements were coded *Agree* (68 codes) and *Strongly Agree* (36 codes). These attitudes may have been influenced by the teachers who could access their materials and those who could not. The implementation logs show that most teachers doubted their ability to meet the needs of SWD in STEM. These logs were taken at various times throughout the school year and could reflect teacher stress levels. There was a decrease in beliefs about SWD learning (3.2), SWD social aspects (3.3), and self-efficacy & confidence (4). Negative qualitative feedback on the implementation logs reflected the decrease in beliefs about SWD learning: “The Smithsonian curricula had more rigor which was extremely challenging for students with cognitive and language challenges.” Participant 3 felt that students might not have been prepared for the complexity of the tasks. The teacher’s declining feelings of self-efficacy may be related to the beliefs about SWD learning and the complexity of the content because the teachers may have felt responsible for the students not mastering the material.

Once May 2021 arrived, the pre- and post-surveys were completed by only two participants with mixed results. For Participant 2, the PD remained a positive overall experience. Participant 3 was less enthusiastic about the program, which could have been a result of this participant not feeling well when completing the survey. It could also be a result of fatigue either from completing the survey or after a very difficult school year.

The program evaluation, also given in May 2021, showed that the teachers were neither positively nor negatively impacted by their attitudes toward meeting the needs of SWD in the classroom when using the Likert-scale data. However, Participant 3 did recognize the importance of self-reflection in this statement: “Addressing student needs requires self-reflecting on the teachers (myself).” The program evaluation also revealed that Participant 2 was encouraged to believe that SWD were capable of doing STEM: “It gives me hope that they are

capable of doing STEM.” She also said that she initially did not feel adequately prepared to teach SWD, but after the program, she did. However, the teacher did find challenges in teaching the curriculum.

The interviews showed a steady positive attitude toward teaching SWD. Participant 1 was excited about the materials and how they could meet the needs of students in the classroom when he said, “Y'all had a race car one [that] was really cool. I took that a little bit further and then kind of added on to it and moved about the race cars.” He also said he “just remember[ed] diving into my kit and taking off with it.” He also had confidence in letting the kids work independently and creatively design experiments: “We took it further as they had to build a -- I forgot the name of it. But you know you set things out like Dominos … all around the room you knock stuff about [Rube Goldberg Machine]”

The findings for this research question are mixed, which reflects the difficult year. It could have been affected by the virtual nature of the school year when the PD was designed to be hands-on for the students. As the year was coming to a close, students were not participating as much, which could have affected teachers' confidence in their abilities to remain engaging. This lack of participation was not necessarily a reflection on them, but rather of the effects of COVID restrictions on public education at large. Gaining perspective from the interviews demonstrated that these two teachers had much more success once they were back in the classroom. Participant 1 supported the assertion that teamwork and a positive administration increased his confidence. There is sufficient evidence that teachers were more positively affected by the program than negatively affected.

Research Question 2: How has the Zero Barriers in STEM PD affected teachers’ implementation and understanding of the tenets of UDL?

Some teachers came into the program with an understanding of UDL. For some, UDL was introduced as part of this PD. The following constructs all showed positive changes from the August 2020 pre- to postsurvey:

- Thoughts about SPED training (Construct 1)
- Beliefs about SWD in general (Construct 3.1)
- Beliefs about SWD learning environment (Construct 3.4)
- Understanding DEAI & UDL(Construct 5)

Teachers felt that teams of teachers learning how to meet the needs of SWD in STEM classrooms were essential. This may have been a new concept for them as well.

When examining results from just one Likert-scale question, “I have the instructional background to teach students with disabilities effectively,” it can be seen how critical it is to use more than one data source for the study. Three teachers’ scores remained the same. Two responses decreased, and two increased, so this is not a significant finding for that question.

The postsurvey on the May 2021 survey showed that Participant 2 had a deeper understanding of some specific UDL strategies:

> “...how to use lab tools or accessible tools, for example, simple denominations on a triple beam balance or larger font for students to see. I would like to create routines in all courses so that students are familiar with accessibility and inclusion routines. For example, scaffolding, differentiation, and accessible text strategies.”

This statement supports the increase in her Likert-scaled score from 2 (*Disagree*) to 3 (*Agree*) on the August 2020 Question 2, “I have been adequately trained to meet the needs of children with disabilities.”

The program evaluation also showed that the teachers had positive attitudes about the content sessions covering UDL, particularly when also being taught how to apply it to a school-wide initiative. “My school can benefit from the open discussions of the need for training and PD for UDL strategies…for all learners” (Participant 2). This statement showed that the PD affected this teacher’s ability to be a leader in the school to effect change.

The interviews held some information about the application of UDL. Participant 2 used more hands-on techniques confidently after the program “with students with disabilities, that

tactile learning is a little bit more exciting than just me going over only notes and concepts." She also had to apply UDL without assistance. "They started taking our collaborative teachers out of our classrooms, so then I really felt like I needed to pick up the pace with what I needed to do" and was able to use "the text to speech. They love that. Most of the UDL strategies work well." Overall, RQ 2 can be answered in the affirmative. The ZBSE PD positively affected the implementation and understanding of UDL tenets.

Research Question 3: How can the Zero Barriers in STEM PD be improved for future iterations?

The program evaluation and interviews were first examined to answer this research question as they were most likely to hold pertinent information. In the interview, Participant 1 shared how he enjoyed the materials being provided as a part of the program: "I don't have to go and find it myself. I don't have to go to the store or get it reordered." However, he did not like the textbook that was provided. When asked if he used the online version, he said, "No, we used the big one. It became awkward for the kids. They were too big and…because of COVID, our spaces were smaller." Overall, he "didn't really find too many barriers in the curriculum." Providing materials and replenishments should be continued with more training on the digital aspects of the curriculum.

Participant 2 said that students' reading levels were far below the necessary levels for the ZBSE program. "Their reading level is, let's say, maybe on a second-grade reading level. Everything has to be scaffolded down; really simplified, but then they have to adjust the content." High-interest/low-reading-leveled articles may be a way to improve the program. The books were leveled, but Participant 2 said, "not to that level." More scaffolding of the curriculum may be needed if the rigor was too high for students, as this finding was replicated in the implementation logs. Here, only a 50% usage of UDL tenets was reported but Construct 5 indicated an increase in sentiment, so better tracking of this aspect of the program would provide better data.

Another way to improve the program would be to adjust the time needed for each lesson. This was a concern at the beginning of the program: “Time allotted for science makes it difficult to do longer activities,” Participant 5 stated on the first survey in August 2020. In both the implementation logs and the interviews, time was a clear barrier to teaching science. Participant 1 noted that “they don't give you the time to plan for that.” When Participant 1 shared the PD with his colleagues, one teacher asked, “‘It's all perfect. Where's the time?’ The only thing is, you got so much other stuff that you got to do [*sic*], especially right now.” If teachers could pick and choose aspects of the lessons that could be tailored to meet the time constraints while remaining hands-on, more teachers may implement the curriculum.

The sentiments about including the content and the SPED teacher supported the team PD model employed by the SSEC. Participant 6 shared, “I feel that my experience coteaching and working closely as a partner to meet the needs of all our students helped me grow as an educator.” Continuing to hold the PD as a team effort was supported in both the PosNonProg codes and PosProg codes and was expressed by Participant 3 in the August 2020 survey: “The range and abilities of students also range from severity and needs. So, having someone who specialized in special education can help me see my content from different perspectives.” Continuing to get district support for team PD would be strongly recommended for future iterations.

Finally, the program evaluation found some specific aspects of the May 2021 PD that the two participants did not find helpful. One was “The Change Game,” a scenario-based conundrum for teams to complete. It was designed to increase team building and teach effective ways of communicating change to all stakeholders, including teachers, parents, and community members. The low scores (M = 3) on this item were likely due to the small number of team participants, but Participant 2 also stated, “It was hard to capture my attention and provide clarity on the directions of the game.”

The program evaluation also addressed some logistics of the ZBSE, like having sessions during the week rather than on weekends. Conducting the PD in person was also recommended because being virtual made it difficult to get commitments from teachers to attend. Again, it cannot be overlooked that the evaluation and the last PD weekend were at the tail end of an extremely draining year for teachers. Having one last PD online after being online all week teaching could have skewed the sentiment in a negative direction that had nothing to do with the program's content. Teachers could attend weekly sessions throughout the school year if they chose to. This final weekend was intended to wrap the program up and send the teachers out with a plan to implement at their schools for the next year.

In answer RQ 3, “How can the Zero Barriers in STEM PD be improved for future iterations?” several parts of the program worked well, like conducting the PD as a team with administrative support and plentiful materials. Only a few areas needed improvement, like eliminating the “Change Game” if too few team members were present to make it worthwhile. Also, adding emphasis on how to differentiate the amount of time needed for lessons would be helpful for teachers with varying amounts of time to dedicate to the program. More scaffolded reading levels for content assignments would also help teachers of students with gaps in their language arts instruction. Leveled Spanish readers could be helpful as students arriving from different countries have varied school experiences and native language reading skills. Overall, the PD was well designed and, with minor modifications, can move the conversation forward on how best to teach STEM content to SWD.

Discussion

There were a relatively equal number of codes between the PosProg, Pos NonProg, and NegNonProg. This result demonstrates the number of factors that affect teachers in their profession. There were significantly fewer NegNonProg codes, indicating that the program did not contribute negatively to their confidence or attitudes. The outside factors that interfered with implementation and teacher morale are significant in the data analysis. Participant 1 lamented,

“There’s just so much being thrown at you.” Participant 2 could not even list specifics, “There is [*sic*] just a lot of factors.” The pandemic affected the teachers' ability to implement new techniques into their classrooms because the program was designed to be in person.

Other outside factors, like the lack of SPED teaching staff, contributed to their inability to apply the ZBSE PD. “We’ve had five hard-of-hearing teachers quit in two years,” Participant 1 said. Participant 3 had similar issues: “Students who require additional supports may not receive it [*sic*] because there is simply not enough human resources to assist.” Unfortunately, this was an issue before the program started, as seen in Participant 1’s Aug 2020 pre- and postsurvey: “I was teaching blind kids, and the system failed to send assistance for the kids, no braille machine and the books in braille didn’t match my curriculum.” The negative quotes were frequently about administrative issues, like the lack of staffing: “Manpower – would like to have more supports for small group pull out” (Participant 3, May 2021 postsurvey).

Holding classes virtually and the impact on student participation was another outside factor frequently mentioned. “We have continued to be virtual, and while I have tried to provide groupings, a bigger issue has been participation and engagement in class on a consistent basis,” said Participant 3. This issue was also noted in the implementation logs by Participant 2”

> Some students really require personal hands-on gratification such as high fives or hugs, while others are inspired by tangible objects like a treasure box, or [a] special seat by the teacher. Children, just like adults, have their own “learning language.” But the barriers of virtual learning have made it difficult to appease all languages.

Participant 5 also saw how “students who never got into the routine of virtual learning struggle to access the materials.” Transitioning to all virtual or hybrid teaching was just as disorienting for the teachers as it was for the students. “As I entered the 2020-2021 school year, I felt like I became a new teacher,” said Participant 1.

A conclusion would be that many outside factors negatively impact teachers’ ability to teach STEM to SWD beyond what ZBSE was designed to address. However, these outside

factors impact how effective any PD could be. The three teachers were still engaged enough in the program to want to continue learning about how to better teach STEM to SWD. However, there were so many outside factors that could affect any individual's attitudes toward teaching any subject in any setting that only specific conclusions about these teachers can be drawn with such a small data set. The ZBSE PD helps districts devise solutions to their own specific issues as a team. This ownership is often missing in education and is a piece that should continue to be implemented.

How This Research Contributes to Current Literature

The design of the ZBSE PD program was rooted in research that showed that a collaborative approach that included all adult team members working with SWD was better able to meet all their students' needs (Bargerhuff et al., 2010; Israel et al., 2013). District administrators were involved from the inception of the program and encouraged to attend so they could also experience the training the teachers would be implementing. The collaborative approach strengthened relationships between the content and SPED teacher as well as with classroom aides who assisted individuals in the classroom (Mutch-Jones et al., 2012). The study was created to carve out time for teams of teachers to discuss curriculum and pedagogy in overcoming barriers to STEM education at both a school and district level. This approach followed the findings of Johnson (2011) and Affouneh et al. (2020) and Yang et al. (2020) who found that educators needed more training time to incorporate the new initiatives effectively.

The professional services team at the SSEC included research-based supports to reinforce the PD throughout the school year. Administrative support was found by Yang et al. (2020) and Affouneh et al. (2020) to be significant for positive teacher PD. The SSEC collaborated with the district administration to allow teachers time to attend PD during their school day by providing substitute teachers. This coverage became less frequent further on in the school year, as substitute teachers became more difficult to procure. However, it was

supported by Affouneh et al.'s (2020) findings that holding PD during contract hours was important for teachers to attend.

The literature review found that positive student identity in STEM could result from teacher confidence in STEM (Aschbacher & Ing, 2017). The ZBSE PD was designed to build both the SPED teacher and the general educator's confidence in each other's specialty. It originally included a student survey component, which had to be eliminated because of COVID restrictions. While student attitudes and confidence in STEM were not a part of the original codebook, it was mentioned often enough that it garnered its own subcategory in this study. This case study showed that using the ZBSE materials and curriculum were positively received by the students as well as the teachers. This finding supports the concept map created at the beginning of the study. It also contributes to the research by supporting the findings of Aschbacher and Ing (2017) when applied to professional development programs.

Aspects of the ZBSE PD program that were not foreseen were documented by Marshall et al. (2020) in their study of the effects on educators of teaching during the pandemic. Teachers in that study mentioned a lack of motivation in students sometimes due to the virtual environment but also to the messages about no accountability in grades. This apathy was also found in this case study. Technology was a barrier to learning as well. It was especially difficult to "meet the needs" of SWD (Marshall et al., 2020, p 48) when not in the classroom. This research study supported Marshall et al. (2020) in the implementation log quotations about students not logging on to learn.

How the Methodology Contributed to Understanding the Data

The study was conducted over 6 months and involved the analysis of multiple forms of data. I used data triangulation of the multiple sources to analyze whether they offered corroboration or contradiction between sources. These data led to "converging lines of inquiry" (Yin, 2018, p. 127), which occur when more than one source supports the case study's findings. A convergent case study design was the best approach to address the attrition issue because

the documents could be analyzed separately and compared. The fact that the program began with 14 responses to the first presurvey in August 2020 then decreased to two participants completing the postsurvey in May shows how difficult the school year may have been on teachers. Only two participants in ZBSE agreed to sit for the interview, as well. However, combining all the data from each document (qualitative and quantitative) provided enough to describe the program's success for the three participants who stayed engaged.

Once the documents' open-ended answers were coded, and the quantitative Likert-scale responses were tabulated, they were compared to each other for convergence and divergence. Then they were applied to each research question to see if the document supplied answers to the questions. These data were tabulated by document and by participant. The summaries were then compiled, and the document results were compared to one another to see if there were similarities.

Limitations

A limitation to the study is that it cannot be applied generally due to the low number of participants by the end of the program. Only two teachers participated in the August 2020 presurvey and the May 2021 post-surveys used to develop the research questions for this study. This circumstance may threaten validity, as participants were already engaged in the program and, therefore, are more likely to have found benefits from implementing the curriculum and techniques.

Other limitations are that this study was conducted in only one school district. Policies about team teaching and curriculum vary by district, so some teachers may not be able to implement the program as designed. The main limitation is how to make standardized conclusions in a completely unusual year. When feelings about the COVID-19 pandemic are parsed out from comments, it appears that the program had a positive effect on teachers. However, the challenges teachers faced in the school year 2020-21 were too great to assume that they did not taint teacher perceptions.

Practical implications

Without being trite, an obvious practical implication would be to not conduct a pilot program in a year of upheaval. It made parsing out the true influences on the PD difficult but not impossible. Conducting the pilot program for the ZBSE PD during COVID-19 pandemic restrictions hindered an accurate and fair assessment of the program. However, some statements could guide the improvement of the program in the future. A teacher stated in August 2020, “I would like to make sure that I am including more ways to access curriculum and content for students while also making sure I consider culture in my instruction.” The May pre- and post-surveys given within the same weekend probably did not provide as much data as answers provided throughout the PD. The implementation logs provided the most information for program implementation in the future. Continuing to train teams of teachers who plan to remain at the school should continue. Providing the materials was instrumental in the teachers using the curriculum as designed. Based on the responses on the implementation logs, more time should be spent on practicing how to apply UDL in the classrooms, so teachers are comfortable integrating the techniques into their everyday teaching. The program originally called for the SSEC staff to join teachers in the classroom to model the techniques and curriculum. This approach should be attempted in the future.

Theoretical Implications

Participant 1 felt that the program allowed him to see intersectional barriers that extended beyond disability in his classroom. He gained confidence from the program to address other issues of inequity in STEM.

> I cleared the barriers out for girls and girls of color in science. Because the barrier was: they don't know what to do because no one's putting them—they're always putting the white boy ahead or any male, in general, but you put females and females of color, and you just show them what they can do, my girls are taking off. It's amazing what they're doing. And now that they're excited about it….My principal noticed it, and I was like, well,

> it's just kind of removing the barrier. The barrier was [that] they don't see African Americans in the field….Think of a scientist. It's the white guy, you know, white hair beard.

The participant did not respond to emails requesting further clarification on what had been proposed. A question to be answered was what this teacher was doing for these girls that are different from other populations and how they would know it was impactful. This qualitative data demonstrated that adding a culturally relevant pedagogy (CRP) would benefit the program overall because providing inclusive environments allows all students to thrive. Including CRP could be used to instruct teachers not to see cultural differences as deficits to be addressed with SPED labels. Culturally sustaining pedagogy (CSP) seeks to sustain cultures while questioning how they have been oppressed by dominant cultures over time. These are important discussions in science and math classes as inventions and discoveries have been whitewashed over time. Building identity in students occurs when they are able to visualize themselves as scientists which is difficult to do if the only images and narratives are of able, white, males. Promoting equality and access means making the learning accessible to the students by honoring all aspects of their identity.

Regardless of background and race, all educators need support and guidance in teaching culturally relevant practices that reach all students in the classroom. UDL utilizes an individualized pathway model similar to CSP by allowing students to learn at multiple intersections of identity. CSP and UDL are asset-based pedagogies that highlight the positive aspects of the differences between individuals while seeking to redistribute knowledge to all learners. CSP can uphold ability as a culture and ability as an aspect of identity. Ability is as much a part of one’s identity as race, gender, and other demographic data. Honoring all aspects of a child’s identity, including exceptionalities, is an essential tenet of CSP. It allows students to

make meaningful and relevant connections to their cultures and heritages in projects and activities.

For example, applying the emancipatory pedagogies of CSP and UDL merges the concepts of honoring individual learning needs. This approach has been coined “cross-pollination” (Waitoller & King Thorius, 2016, p.1) and may allow schools to move past labeling children and their abilities. UDL employs many best practices that address learning needs throughout lessons without placing abilities on a hierarchy, much like CSP accepts various cultures without placing one above another. By utilizing this cross-pollination framework, teacher confidence can be increased by applying these theories to their content delivery (Bilican et al., 2021; Trygstad et al., 2013).

While disabilities are not explicitly included in the practice of culturally responsive pedagogy (CRP), many of the tenets still apply. CRP acts to disrupt the perpetuation of racism in American society by celebrating all aspects of a student. Students are recognized as unique learners and encouraged to bring their perspectives to class to create knowledge based on their experiences. Lessons are more relevant when weaving in student culture to enhance learning (Ladson-Billings, 1995). PD on CSP provides training on specific aspects of the instructional congruence framework, incorporating students’ home cultures into elementary science inquiry lessons (Cuevas et al., 2005; Johnson, 2011). By seeking to understand and appreciate students and their backgrounds, CSP may be a way to reduce the number of minority children placed in special education and could increase the number placed in gifted education (Bryan & Williams, 2017).

Bryan and Williams (2017) contended that teacher preparation classes must be deliberate in their inclusion of CRP. Teachers who attended CRP training reported increased use of real-world examples and scaffolding, which can positively impact underrepresented populations’ understanding and sense of belonging (Johnson, 2011; Scalise et al., 2018). This also is a way to improve teaching to SWD. Teachers can create more equitable classrooms by

using CRP to embrace student input and dialogue, resulting in more understanding of scientific phenomena.

However, preservice teachers have found that CRP information integrated into coursework varies in effectiveness (Lew, 2016). Classes may only mention majority-minority groups, focusing on specific cultures rather than how to incorporate general CRP into the classroom climate. When focusing specifically on science, the current curriculum and pedagogy is teacher-centered and is taught with few perspectives aside from those of the contributions of able, white, male scientists (Mensah & Jackson, 2018). When science is not accessible to minority students, they exit school without the necessary science literacy to be critical thinkers.

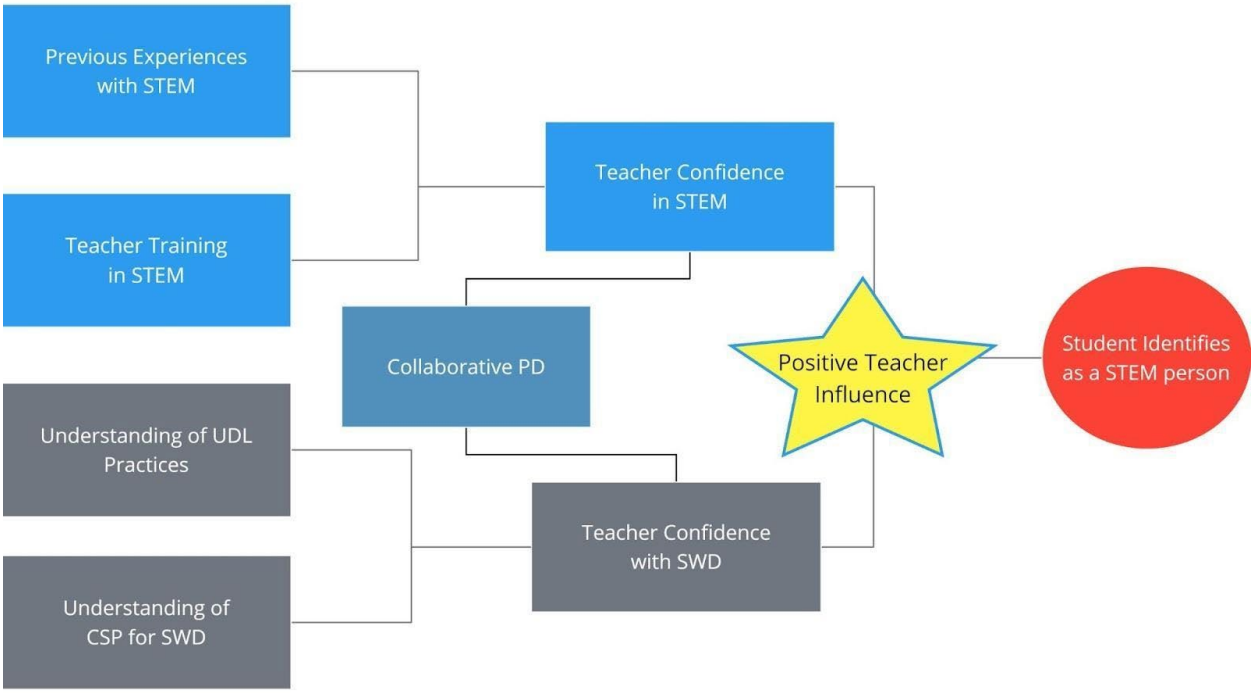
Combining sessions on CRP and how it applies to SWD could be a way to improve outcomes for students and confidence in teachers.

Revised Conceptual Model

The initial concept map showed that positive PD could influence teacher confidence with the proper support. Positive student outcomes were omitted because the study dropped student surveys. However, when running a code cooccurrence table, positive student results aligned with positive program implementation. The positive implementation also cooccurred with the application of UDL. When separated from the program, it was also found that positive attitudes toward STEM led to positive student responses unrelated to the program. This validates the proposed revised concept map (Figure 14).

Figure 14

How Teacher Training Influences Student Identity



When discussing using the materials, Participant 1 said, “The kids are allowed to go through the kit. They pull things out. They went further than what I was doing in the lesson.” At another point, he said, “The kids kind of did that on their own. ‘Can we do that?’”

“The kids enjoy the modeling aspect of the activities,” said Participant 2. “They like the fact that once they do something, now we can go over the understanding and see if you can apply the concepts and learning to the modules.” She also said later in the interview that “....whenever you can apply the models, the modules *[sic]* to their learning, that’s what makes it exciting for them.”

Participant 2 spoke of other kids' excitement seeing the materials being set up for the eighth-grade class, and the anticipation students have about using the materials of the program:

> “Tell us what you’re doing. What are they doing? What are they doing?” “I'm getting ready for them. I have to put the stuff out, and ya’ll continue to do your work while I set

> up for the next class." Oh yeah, you know they're like, "Why can't we do that? When do we do that," and they look into the windows. "What are they doing?" I say, "Nope, these are eighth-graders. You do this when you get to eighth grade."

Participant 1 enjoyed having small groups of deaf and hard-of-hearing students who would attend his class as a small group:

> They used to love coming into my room just them because I taught. I taught the pre-K to fifth grade. It was hard. But I did it, and it's fun. They went off on their own. They touched whatever they wanted and played with whatever they wanted to.

He could reach out to them and give them the individualized attention they needed. Unfortunately, a lack of staffing put the kids into the much larger collaborative class.

> 'So, they just stay at the round table, and I can't move them around the room to integrate to other ones because I got to have them near an interpreter. So, you went from being able to do whatever you want to "I can't, buddy. I got 25 kids now." Personally, I know, and I said this, "I'm not doing anything for them." They are not getting anything out of my lesson, and I don't know what else to do. Because there's no support. (Participant 1)"

This quotation shows that the teachers utilizing engaging materials and curriculum energized the students, particularly when supported by collaborative teachers, further supporting the conceptual model. The student attitudes and confidence component of the original pilot program would be a valuable addition to future studies.

Recommendations for Future Research

PD is essential for helping teachers grow in their practice. Applying research-backed practices in this PD most likely made the program more effective for the teachers who attended. The ZBSE PD has moved beyond this pilot stage and is being offered for the next school year beginning this summer. Further research from that program will provide more data for comparison between a pandemic teaching year and a more typical in-person year. Research on

student attitudes toward science would be another way to measure the program's success and was initially a part of the pilot ZBSE program.

Other research could include piloting a “cross-pollination” PD to see how collaborative teams can use CRP tenets to accurately address the intersectionalities that are part of every student. This approach could follow the same basic model as the ZBSE but would add CRP to the sessions and offer comparisons to UDL. Including other equally important aspects of student identity besides ability would help teachers see students as individuals.

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Appendix A: Teacher Pre/Post Attitude Survey (Administered via Moodle)

Teaching Grade:____ Special education ( )

General education( ) Other (please specify)

Teaching Subject: _____ In-person class only ( )

How will you teach this school year? Both online & in-person ( )

Online class only ( )

How many years have you taught? _____

Do you have special education training experience? Yes ( ) No ( )

If yes, please specify, how long and what: _____

(n) indicates a reversed question.

Constructs	Items (Scale range: 1 Strongly Disagree – 4 Strongly Agree)
1. Special education training experience (Q1-3)	Q1. I have the instructional background to teach students with disabilities effectively. Q2. I have been adequately trained to meet the needs of children with disabilities. Q3. My lack of special education training hinders my ability to teach students with disabilities effectively. (n)
2. Thought about Special Ed training (Q4-5)	Q4. Special in-service training in teaching students with disabilities should be required for all regular education teachers. Q5. Special education training is not necessary for general education teachers because it is more beneficial for special education teachers to take care of students with disabilities in class. (n) (open-ended) Please explain why you chose your answers in the questions 4 and 5.
3. Beliefs about students	**3.1. Beliefs about students with disabilities in general** Q6. Students with disabilities should be included in regular education classrooms.

with special needs	Q7. All efforts should be made to educate students with disabilities in the regular education classroom.
(Q6-7) **(Q8-10)** **(Q11-13)** **(Q14-16)**	**3.2. Beliefs about students with disabilities in terms of learning** Q8. Although children differ intellectually, physically, and psychologically, I believe that all children can learn in most environments. Q9. Students with disabilities have higher academic achievements when included in the regular education classroom. Q10. It is difficult for children with disabilities to make strides in academic achievement in the regular education classroom. (n)
	3.3. Beliefs about students with disabilities in terms of social aspects Q11. Self-esteem of children with disabilities is increased when included in the regular education classroom. Q12. Students with disabilities are socially well adjusted in the classroom. Q13. Students with disabilities learn social skills that are modeled by regular education students.
	3.4. Beliefs about learning environment with Special ed students Q14. Students with disabilities in the regular education classroom hinder the academic progress of the regular education student. (n) Q15. Students with disabilities have a negative impact upon the learning environment of my classroom. (n) Q16. The inclusion of students with disabilities affects the learning climate of my classroom. (n)
4. Self-Efficacy and	Q17. I am confident in my ability to teach children with disabilities. Q18. I can be effective with students with disabilities in my classes. Q19. I become easily frustrated when teaching students with

Confidence **(Q17-21)**	disabilities. (n) Q20. The presence of students with disabilities in my regular classes affects upon my implementation of curriculum content. (n) Q21. I can create a welcoming space for students with disabilities.
5. Thoughts about applying UDL in class **(Q22-25)**	Q22. I am familiar with the term, Universal Design for Learning (UDL). *Q23. Utilizing UDL in class benefits to only certain group of students. (n) *Q24. It is not worthwhile to revise my lessons to be accessible for all students in terms of my time and efforts. (n) *Q25. I understand that applying UDL in class can be beneficial to my students, but I think the effect will be minimal. (n)
	Open-ended questions: What challenges do you face in including students with special needs in your class?

Appendix B. Teacher Bi-Monthly Implementation Log

Data Collection

Every other month: October, January, March, and May

Platform*: Moodle*

Name:	
Current Teaching Grade: Current Teaching Subject: Current Teaching Format: Online class only ( ) In-person class only ( ) Both online and in-person ( ) Number of students you currently teach: Number of students with disabilities in your class: Please describe the context of your class if you have students with disabilities. (e.g. how many hours you teach, what supports they need, how you cooperate with a special education teacher, etc.)	

Constructs	**Items**	**Notes**
Supports	*Likert-Scale: 1 (strongly disagree) – 5 (strongly agree)* **Supporting effort by self** 1. I have adequate preparation time for students with disabilities placed into the regular classroom. **Material Support** 2. Adaptive materials and equipment are easily acquired for meeting the needs of students with disabilities. **Administrative Support** I can approach my administrators with concerns I hold regarding teaching students with disabilities.	

	Colleague Support 4. I can approach my colleagues for help with issues that may arise when I have students with disabilities in my class.	
UDL Implementation (CAST Guidelines)	*Likert-Scale:* *1: Never, 2: Rarely (<20% of the time), 3: Sometimes (20-50% of the time), 4: Often (50-80% of the time), 5: Almost Always (80-100% of the time)* 6. I utilized UDL in my class regularly.	
Multiple Means of Representation	7. As appropriate, I provide options for perception by presenting information in more than one format (e.g., text, oral, multimedia). 8. I use instructional strategies to clarify key terms, vocabulary and symbols related to the content that I am teaching. 9. I use instructional strategies that provide scaffolds for comprehension (e.g., highlighting key concepts, connecting to background knowledge).	
Multiple Means of Action and Expression	10. My students have access to instructional and assistive technologies as needed (e.g., digital text for students with literacy-related disabilities, technology tools to communicate). 11. I provide opportunities for students to express their knowledge in varied formats (e.g. verbal, written, drawing, through physical demonstration). 12. I guide my students to set goals for themselves during the learning process.	
Multiple Means of Engagement	13. I use instructional strategies to minimize threats and distractions for students.	

	14. I use collaborative grouping strategies with the goal of supporting students with persistence and effort. 15. I provide opportunities for my students to assess their own progress and self-reflect on their learning.	
Instructional Strategies Implementation	Please check the strategies that you implemented in your class in the last months. (Choose all that apply) ( ) Utilized inclusive digital tools (e.g. Kahoot, Bookshare, Raz-Kids, Google suite, QR code, etc.) ( ) Students were offered with different learning stations. ( ) Manipulatives were used following the Concrete-Representational-Abstract method. ( ) Students created dictionaries. ( ) Total Physical Response method was used. ( ) Identity mapping was implemented in instruction. ( ) Cooperative group strategies were used. ( ) Arranged peer support for each pair of students. ( ) Classroom norms were developed and shared in class. (open-ended) Please describe how and in what context you implemented the strategies. What do you think went well and what did not go well, and why?	
Curriculum Implementation	*Likert-Scale:* *1: Never, 2: Rarely (<20% of the time), 3: Sometimes (20-50% of the time), 4: Often (50-80% of the time), 5: Almost Always (80-100% of the time)* 16. I taught the *Smithsonian Science for the Classroom* curriculum.	

	17. (open-ended) Please describe how and in what context you implemented the curriculum in your class. What do you think went well and what did not go well, and why?	
Self-Efficacy **Thoughts about students**	*Likert-Scale: 1 (strongly disagree) – 5 (strongly agree)* I am comfortable creating inclusive classroom norms for my students. 18. I am confident incorporating UDL strategies in my lessons. 19. I am confident teaching the *Smithsonian Science for the Classroom* curriculum. (open-ended) What are your challenges in creating inclusive classroom culture and/or implementing UDL strategies in lessons? 20. I think my students cared for each other. 21. I think my students felt comfortable in my class. 22. I think all my students were involved in my class. 23. I think my students did not go well with students with disabilities. (n) * * add the option: Not applicable. (open-ended) Please describe your classroom culture in general. What do you think your students respond to the inclusive instruction? Any changes have you observed on your students becoming more inclusive?	

Appendix C. 2021 Virtual Zero- Barriers in STEM Education Summit Program Evaluation Questions

Demographic Information (for both Day 1 and Day 2 survey, anonymous)

What is your primary position?

□ K-5 School Administrator

□ K-5 Teacher; Teaching Subject: _____

□ 6-8 School Administrator

□ 6-8 Teacher; Teaching Subject: _____

□ Other _____

Day 1	Questions	Sessions/Notes
	Open -ended question: ● What ideas or concepts did you take away or will you implement from today's sessions?	
Day 1 program	Please rate today's sessions in the following questions. (1: Strongly disagree, 2: Disagree, 3: Not sure, 4: Agree, 5: Strongly agree, NA: Not applicable)	
	1. The overview session in the morning was clear and aligned with the Summit goals and agenda. 2. I understand how to fill in the action plan template.	Introductions and Overview
	3. Creating a team identity map helped to strengthen relationships with my team members 4. Creating an identity map with team members helped me gain confidence in preparing to develop an action plan.	Team Identity Map (team building)
	5. The "Change Game" simulated experience expanded my understanding of systemic change. 6. The "Change Game" simulated experience exposed potential barriers to implementing our team's goal.	Change Game
	Open-ended questions: ● What questions do you have about the work today? ● What programmatic or logistical suggestions do you have for improving this virtual Summit?	

Day 2	Questions	Sessions/Notes

Programs during the week	Please rate your experience in the following programs over the past week. (1: Strongly disagree, 2: Disagree, 3: Not sure, 4: Agree, 5: Strongly agree, NA: Not applicable) 1. Hearing the panelists' perspectives on why a focus on accessible and inclusive STEM learning is beneficial to the STEM learner and for the STEM industry was useful. 2. "Sharing Different Perspectives" (Asynchronous): This discussion forum helped me to think critically about **my own perspective** on accessibility and inclusion in STEM instruction. 3. "Sharing Different Perspectives" (Asynchronous): I gained **new** perspectives about accessible and inclusive STEM instruction.	Mon. – Fri. Asynchronous Pre-recorded Panel Discussion "Sharing Different Perspectives"
	4. "DCPS Resources and Strategic Plan to Address More Accessible and Inclusive Learning" (Synchronous): Learning about what one district is doing to improve accessibility and inclusivity in their school system was useful. 5. "DCPS Resources and Strategic Plan to Address More Accessible and Inclusive Learning" (Synchronous): I gained new ideas after talking to other educators about what they are doing in their classrooms.	Wed. Synchronous Strategies for A/I STEM learning

	6. “Team pre-work” (Synchronous): It helped me to identify the root cause of the problem that our team is trying to solve. 7. “Team pre-work” (Synchronous): It helped me understand how to separate symptoms from causes.	Fri. The 5 Whys Technique
Day 2 program	Please rate today’s sessions in the following questions. (1: Strongly disagree, 2: Disagree, 3: Not sure, 4: Agree, 5: Strongly agree, NA: Not applicable) 8. We received sufficient guidance to use our team’s worktime for writing our problem statement and goal effectively. 9. We received sufficient guidance to use our team’s worktime for writing our outcomes and program evaluation tools effectively. 10. We received sufficient guidance to use our team’s worktime for writing our activities, owners, and resources effectively.	Team worktime - Problem Statement and Goal - Outcomes and Program Evaluation - Activities, Owners, Resources
	11. During the "Think Tank" I was able to solicit constructive feedback from my peers on my team's action plan progress. 12. The "Think Tank" enabled me to practice communicating my team's plan to others effectively.	Think Tank
	13. Reviewing my peers' action plans in Moodle gave me new ideas for my team's action plan. 14. Feedback left by our peers during the sharing time helped my team to uncover new ideas for our action plan. 15. The session on Messaging increased my comfort with communicating about our action plan.	Messaging and Keynote Speaker

	16. I feel empowered to be a change agent and support the action plan developed by my team.	
Overall Program	Please rate the Zero Barriers in STEM Education Summit overall in the following categories. (1: Not at all, 2: A few, 3: Some, 4: Mostly, 5: All of them) 17. Overall, the presenters facilitated each session knowledgeably. 18. Overall, the presenters were engaging and held my attention. 19. Overall, the presenters provided clear instruction to guide our team's work.	Presenters
	(1: Strongly disagree, 2: Disagree, 3: Not sure, 4: Agree, 5: Strongly agree, NA: Not applicable) 20. Overall, the sessions were well-organized. 21. Overall, the information presented at the Summit was useful in forming our action plan. 22. Overall, the sessions helped me to grow my understanding of accessibility and inclusivity in K-12 STEM learning.	Sessions contents
	23. Overall, it was easy to navigate and access the information in Moodle. 24. Overall, the information presented in Moodle was well-organized. 25. Overall, resources presented in Moodle were useful.	Moodle
	26. I felt that we had adequate planning time to construct our action plan. 27. My team felt equipped to use our planning time effectively. 28. It was clear what our tasks were during each team planning time. 29. Our school will benefit from our participation in this summit. 30. I have a clear idea of my role in implementing this plan. 31. I am excited to implement the activities we have designed to meet our goal. 32. Overall, this summit was a useful development experience for me. 33. I would recommend attending this summit to my colleagues.	General Thoughts

	34. Our school will benefit from our participation in this summit.	
	Open-ended questions: 35. How do you expect your school to benefit from your work at the Summit? 36. What ideas or skills did you take away from the Summit that you didn't have before? 37. Please comment on the most useful part of this experience. 38. What programmatic or logistical suggestions do you have for improving this virtual Summit?	

Appendix D . Zero Barriers Interview protocol

I. INTRODUCTION:

Hello, thank you for agreeing to help me with my dissertation project. I appreciate your time and will do my best to stay within our 60- minute time frame. I will be sending you a gift card after you fill in the Participant Info Spreadsheet at the end of our conversation. But first, let me tell you a bit about myself. My name is Alison Dossick, and I am a graduate student at VCU. Last spring I was a Douglas Lapp Fellow at the Smithsonian Science Education Center where I assisted in the Zero Barriers program. What I learn from today's discussion will be shared with my dissertation committee and the SSEC's research scientist. All responses will be recorded via Zoom and using an external recording. Both will be destroyed at the conclusion of the project.

---- BEGIN RECORDING ---

Before we begin, we will review some guidelines that will help the session run smoothly. With your permission, we will be audio recording the session so that we can accurately capture all of your comments.

· In order to keep to our 45–60-minute time frame, please silence and put away your cell phone and any other distractions.

· I want to assure you of complete confidentiality, so please only use your first name or a pseudonym during today's session. In the written summaries of the session, no names will be attached to specific comments. I will be recording this conversation via Zoom and externally. After the transcript is created, the recording will be destroyed.

· Do I have your permission to audio record the conversation externally?

· I am interested in all of your viewpoints – both positive and negative. When responding to the questions, please omit specific names of individuals who are not here, such as peers, Smithsonian facilitators, and staff, or administrators.

Very briefly, can you tell your preferred name and the grade level you are teaching in the 21-22 school year and is it virtual or in-person?

RQ 1	How has the Zero Barriers in STEM PD impacted teacher attitudes towards meeting the needs of SWD in the classroom?	Sessions/Notes
	1. How have your beliefs about teaching STEM to SWD in general changed since the end of the PD? 2. How has in-person teaching affect these beliefs and attitudes? 3. What lessons from the PD influenced your ability to teach STEM to students with disabilities?	
RQ 2	How has the Zero Barriers in STEM PD affected teachers' implementation and understanding of the tenets in UDL.	
	4. Did you feel adequately prepared to teach STEM to SWD? 5. Were there any specific lessons or techniques that you were able to apply to your teaching?	
RQ 3:	How can the Zero Barriers in STEM PD be improved for future iterations?	
	6. What barriers or challenges did you experience while teaching the curriculum? a. Were these related to Covid? 7. How has the support from colleagues impacted your ability to implement the strategies? 8. How has your prep time or effort changed as a result of the PD?	Probing Question

CLOSING:	9. Is there any other information you would like to share about your experience teaching with the Zero Barriers in STEM program? 10. May I email you the transcript for you to look over for accuracy or to clarify anything?	

I will keep your email address until the dissertation is defended which will be by the end of the summer 2022. It will not be shared and will be encrypted and stored on a password-protected computer. Thank you so much for your time today.

Appendix E: Consent Form

Zero Barriers in STEM Dissertation Project Information and Consent Sheet

I am a doctoral student with VCU's School of Education and am working with the Smithsonian Science Education Center's (SSEC) Zero Barriers in STEM professional development program. They are permitting me to use the data collected through the surveys and implementation logs for my dissertation. I would like to plan a follow-up interview with you. Your time will be honored with a $25 gift card to a place of your choosing. Total payments to you from VCU within one calendar year that exceed $600 will require the University to report these payments annually to the IRS and you. This may require you to claim the compensation you receive for participating in this study as taxable income. VCU is required by federal law to collect your social security number. Your social security number will be kept confidential and will only be used to process payment.

- I am inviting teachers who participated in the Zero Barriers Program and who filled out 2 out of 3 Intervention logs and the Pre and Post Surveys.
- The interview should take around 45-60 minutes and will be conducted virtually. Summary results will be shared with dissertation committee members and the SSEC.
- Participation is voluntary and you may leave the interview session at any time during the meeting.
- With your permission, the conversation will be recorded using an external audio recorder to ensure that I accurately capture your experiences and the information shared
- All recordings will be destroyed after the transcript is made and verified
- No identifying information will be collected or recorded. It will not be possible to identify individual participants based on the written paper or presentation.
- You may use a pseudonym if you prefer.

- Thank you for your willingness to consider participating in this project. To compensate you for your time, I'd like to send you an e-gift card of your choice after we meet.
- If you have questions, please don't hesitate to contact me, Alison Dossick at dossicka@vcu.edu or Dr. Elizabeth Edmondson ewedmondson@vcu.edu

Appendix F Code Book

Code	Comment	Code Group 1	Code Group 2	Code Group 3	Code Group 4
Neg attitude towards SWD	Teacher has negative attitudes towards SWD	Neg Non Prog			
Neg Teacher Confidence	Teacher does not feel confident teaching STEM	Neg Non Prog			
Negative Admin	Teacher feels that admin makes choices that undermine teaching STEM. This can be scheduling and coverage with teachers.	Neg Non Prog			
Negative due to Covid	Covid has negatively impacted teaching	Neg Non Prog			
Negative Materials/resources	This is not due to Zero Barriers but to the other resources being thrown at the teachers.	Neg Non Prog			
Negative outside factor	This is virtual teaching or low abilities of students due to virtual teaching or other deficencies.	Neg Non Prog			
Negative Student	Students do not want to learn STEM or begin to show that they are doing poorly in STEM	Neg Non Prog			

result/attitude					
Negative Team	Teacher's team members are not supportive of them	Neg Non Prog			
Negative time	Prep time is increased due to something other than the ZBSE program	Neg Non Prog			
Negative Virtual	This covers negative sentiments about teaching virtually no program related.	Neg Non Prog			
Negative Prog Implementation	The ZBSE implementation has been negative.		Neg Prog		
NegProg admin	Admin does not support ZBSE		Neg Prog		
NegProg Materials Resources	The materials provided by ZBSE are not useful or adequate		Neg Prog		
NegProg teacher confidence	ZBSE has decreased teacher confidence to teach STEM		Neg Prog		
NegProg Time	ZBSE has increased the amount of prep time or classroom instruction time		Neg Prog		

NegProg virtual	ZBSE is not good virtually		Neg Prog		
NegProgram team	Team of teachers feels negatively about ZBSE		Neg Prog		
Positive admin	Admin supports STEM in general			Pos Non Prog	
Positive Attitude towards SWD	Teacher has positive attitudes toward teaching SWD			Pos Non Prog	
Positive In person	Teacher mentions positve sentiment when teaching in person.			Pos Non Prog	
Positive Student results/attitude	Students have a positive attitude about STEM			Pos Non Prog	
Positive Teacher Confidence	Teachers feel confident teaching STEM and SWD			Pos Non Prog	
Positive Virtual	Teachers have positive attitude towards teaching virtually			Pos Non Prog	

PosProg Admin	Admin supports ZBSE				Pos Prog
PosProg Confidence	ZBSE has increased teacher confidence				Pos Prog
PosProg implementation	Teacher has positive sentiments about ZBSE implementation				Pos Prog
PosProg Materials/resources	Teacher has positive sentiments about the materials				Pos Prog
PosProg Self Efficacy	ZBSE has increased teacher self-efficacy				Pos Prog
PosProg Team	Team has positive reaction to ZBSE				Pos Prog
PosProg Time	ZBSE has a positive effect on prep or classroom time.				Pos Prog
Postive Team	Team is supportive of STEM in general			Pos Non Prog	
Postive Time	Prep time is at a tolerable level.			Pos Non Prog	
self efficacy	This is due to Covid and being in person then out and hybrid for the 2020-2021 SY			Pos Non	

				Prog	
Self reflection	Teachers offer reflection on their practice.			Pos Non Prog	