Closing the Gap: Addressing the Deficiency of STEM Professional Development for Elementary Educators

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To meet the demand for STEM-literate workers, elementary and secondary schools are integrating STEM curriculum and pedagogy into their daily routines. According to the National Academy of Engineering and National Research Council (2014), STEM literacy entails understanding the roles of science, technology, engineering, and mathematics in modern society, grasping fundamental concepts from each area, and applying these skills fluently in everyday contexts (p. 34). With 2.4 million unfilled STEM jobs for every unemployed STEM graduate (National Science Board, 2012), the economic imperative for producing STEM-capable students is clear. To maximize students' STEM potential, schools must enhance their STEM education efforts and refine instructional practices. Gomez and Albrecht (2013) advocate an interdisciplinary STEM pedagogy that connects learning to real-world applications, preparing students for future STEM careers.

Initiatives have begun to integrate engineering and technology into traditional math and science classrooms, promoting project-based learning through the engineering design process (National Science Board, 2007). This approach encourages students to apply their knowledge to solve practical problems, aligning with effective STEM pedagogy where learning occurs through hands-on experience. However, neglecting STEM and science education in favor of prioritizing other subjects can hinder overall academic achievement in reading and math (Royce, 2024).

Research indicates that broad background knowledge correlates with better reading comprehension, as prior experiences enrich students' understanding of text content (Schwartz, 2024). Educators can foster connections that enhance reading comprehension and overall academic achievement by allowing students to explore, engage, and investigate STEM concepts.

The theory of improvement in my dissertation aims to observe teachers' actions and reactions to their involvement in a "just in time" STEM kit professional development, Professional development serves as the primary driver for this change, aiming to validate its effectiveness within my elementary school. This approach underscores the critical role of ongoing teacher training in building confidence and competence in STEM education, preparing educators to effectively integrate STEM across the curriculum and enhance student learning outcomes.

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1.0 Naming & Framing the Problem of Practice

1.1 Broader Problem Area

STEM (Science, Technology, Engineering, and Mathematics) education, as defined by the Pennsylvania Department of Education (PDE), is "an integrated, interdisciplinary, and student-centered approach to learning that encourages curiosity, creativity, artistic expression, collaboration, computational thinking, communication, problem-solving, critical thinking, and design thinking" (PDE, 2024). The acronym STEM is relatively new, but the U.S. has long pursued education and innovation in Science, Technology, Engineering and Mathematics fields. The onset of STEM began with the Morrill Act of 1862 which established land grant universities to promote agricultural science and later engineering programs, advancing education and influencing the US workforce. During World War II, collaboration between the military, businesses, and academia led to significant technological advancements. The Cold War and the space race further intensified U.S. interest in science and technology, exemplified by the creation of NASA in 1958 and the National Defense Education Act of 1958. This era culminated in the moon landing in 1969, driven by a national focus on scientific progress. Advances in science, technology, and engineering cultivates a culture of creativity, curiosity, and experimentation. For example, the 1970s and 1980s saw advancements like the development of the first computers, cell phones, artificial heart, and space shuttle landing, reinforcing the need for robust science education. Education initiatives like the Next Generation Science Standards (NGSS) recognize STEM fields' growing importance to innovation, economic growth, and global competitiveness, supporting the need for early STEM integration in elementary curricula to cultivate students' interest and proficiency in these fields.

STEM education integrates artistic expression and communication with humanities, allowing students to explore fundamental human questions while understanding the natural world and developing problem-solving skills. (Choi & Pak, 2006; Holbrook & Rannikmäe, 2014; Yakman, 2008).

However, since the 1800s, standardized testing has dominated education, narrowing it to students' performance or mastery of knowledge (National Education Association, 2020). This focus has widened the achievement and opportunity gaps and increased the pressure to prepare students to be proficient at attaining high scores on standardized tests. Teaching to the test often leads to an overemphasis reading and mathematics literacy, neglecting other subjects like science, technology, and engineering. Educational policies emphasizing standardized testing and accountability contribute to this issue by deprioritizing non-standardized tested subjects.

In Pennsylvania, elementary students in grades 3 and 5 are primarily tested on reading and mathematics, with science only tested in grades 4 and 8. In school districts that emphasize standardized testing, science and STEM is often excluded from daily instruction, which is inequitable for students depriving them of learning and applying scientific knowledge and skills. According to the National Academies of Sciences (2012), equity in science education-related STEM pedagogy requires providing all students with opportunities to learn and engage in science, supported by quality instructional time and pedagogical resources. Fearing administrative backlash, educators adhere strictly to curriculum and pacing guides, stifling creativity, and cross-curricular integration approaches like STEM pedagogy and neglecting project and inquiry-based learning strategies.

The challenge for K-12, particularly elementary teachers, lies in understanding how to teach STEM in a way that connects its components: Science, Technology, Engineering, and

Mathematics (Brophy et al., 2008; Dare, 2018; Honey, Pearson, & Schweingruber, 2014). Integrated STEM education goes beyond worksheets and rote memorization. It emphasizes procedural fluency in mathematics and process-driven inquiry in science, both essential to STEM activities. Integrating STEM offers deeper learning opportunities by normalizing struggle and uncertainty, fostering a productive problem-solving environment where students iteratively test and refine solutions. Effective STEM education requires a transdisciplinary approach that many elementary teachers are not trained to implement.

1.2 STEM as a Transdisciplinary Praxis

Transdisciplinary theory and practice (praxis) integrates concepts, methods, and skills from multiple subjects to address real-world problems, rather than focusing on individual subjects like math, science, or language arts. This approach connects new knowledge to real-life experiences, promoting critical thinking, creativity, and collaboration among teachers and students. According to Bosch (2018), transdisciplinary education aims to train students to be thinkers rather than just specialists by addressing complex, real-world issues that require knowledge and skills from multiple disciplines. This method emphasizes the integration of various fields to foster a deeper understanding and practical application of knowledge in addressing societal challenges (Bosch, 2018). Additionally, the Smithsonian Magazine (2018) describes transdisciplinary education as an approach where disciplines converge, allowing students to apply knowledge and skills from various subjects to solve real-world problems, enhancing their learning experience and engagement (Smithsonian Magazine, 2018).

Transdisciplinary learning involves project-based activities where students apply knowledge and skills from various disciplines to solve problems and create products. This method emphasizes the interconnectedness of knowledge and encourages hands-on, inquiry-based learning. According to the International Baccalaureate Organization (2023), this approach contextualizes and applies learning beyond traditional school boundaries, helping students understand and engage with the world around them.

Integrating STEM disciplines with the humanities and social sciences allows students to explore socio-scientific inequalities and understand that issues extend beyond technical solutions. This method highlights the intersection of STEM with human dignity, rights, and futures (ASCD, 2023).

In elementary education, transdisciplinary STEM instruction fosters holistic learning experiences that emphasize real-world applications and problem-solving skills. However, successful implementation relies on educators' competence and confidence in using STEM tools and methodologies. Comprehensive and targeted professional development (PD) programs are essential to supporting teachers in enhancing their pedagogical strategies and content knowledge, ultimately cultivating a culture of inquiry and critical thinking among students. Bridging the gap between transdisciplinary STEM instruction and professional development is crucial for meaningful and sustainable educational outcomes. Addressing the challenges of STEM education in K-12, particularly for elementary teachers, involves providing targeted professional development (PD) and resources to build teachers' self-efficacy in STEM. Effective PD should be sustained over time and include active learning and collaborative participation to enhance teachers' confidence and skills in STEM integration (Darling-Hammond et al., 2017; Kennedy, 2016; Ufnar & Shepherd, 2019). Research has shown that engaging in inquiry-based teaching, engineering

design processes, and real-world problem-solving during PD significantly improves teachers' STEM teaching self-efficacy and pedagogical content knowledge (Ertmer et al., 2014; Hammack et al., 2020; Peters-Burton et al., 2015).

1.3 STEM Professional Development

Effective STEM integration in elementary classrooms requires meaningful professional development (PD) for teachers. According to EdWeek, in underperforming schools, PD often focuses on raising test scores rather than improving teaching practices (Schwartz, 2020). This leads to inconsistency in the quality and relevance of PD that teachers receive.

A study found that while 90 percent of teachers participated in PD, most found it to be ineffective (Darling-Hammond et al., 2009). In my district, PD primarily focuses on reading, math, or social-emotional learning, with little emphasis on science instruction. To teach STEM successfully, teachers must be confident in their STEM knowledge and abilities.

Professional development (PD) programs designed for STEM education can significantly enhance teachers' competence and effectiveness. These programs often include workshops, seminars, and collaborative learning opportunities, providing new pedagogical strategies, content knowledge, and practical skills (Glynn et al., 2009; Goktas et al., 2008). Such programs help teachers develop their expertise in STEM subjects and improve their instructional practices.

Moreover, fostering communities of practice within schools or districts allows educators to collaborate, share best practices, and receive ongoing support from peers and mentors. This collaborative environment enhances teachers' confidence and competence in STEM education (Hudson et al., 2004; Byars-Winston & Dahlberg, 2019). These communities are instrumental in

promoting continuous professional growth and addressing challenges faced by educators in implementing STEM curricula.

Integrating technology-enhanced learning tools into PD initiatives can also improve teachers' proficiency with digital tools and platforms, enabling them to facilitate STEM instruction effectively. Hands-on experiences with technologies like virtual simulations, coding platforms, and data analysis software help teachers explore new instructional methods and innovative teaching techniques (Koehler & Mishra, 2005; Kim et al., 2013).

Mentorship programs play a crucial role in nurturing teachers' confidence and competence in STEM education. Pairing novice educators with experienced mentors provides personalized guidance, professional advice, and targeted feedback, fostering a collaborative learning environment. This mentoring relationship supports novice teachers' growth, professional development, and confidence in implementing STEM curricula (Aspfors & Fransson, 2015; Bradbury, 2010).

High-quality and ongoing professional development can advance teachers' capacity and reduce turnover rates. Consistent participation in high-quality PD has “significantly impacted the improvement of student achievement across various disciplinary foci” (Zhou, Shu, Xu, & Padron, 2023).

The review of literature on professional learning supports the efficacy of PD programs in bolstering teachers' confidence and competence in STEM education. Effective PD initiatives often incorporate hands-on experiences with STEM kits, which provide practical knowledge and skills that teachers can immediately apply in their classrooms (Beers, 2018; Jones & Carson, 2020). These kits include materials designed for inquiry-based learning and problem-solving activities,

aligning with constructivist principles that emphasize active engagement and discovery (Bybee, 2013).

Research indicates that short, intensive PD sessions can be highly effective in promoting teachers' self-efficacy in STEM. These sessions deliver focused content, allowing educators to deepen their understanding of specific STEM concepts and instructional strategies within a limited timeframe (Dare, 2017; Wessling & Howell, 2019). By integrating these sessions into educators' daily schedules, such as during planning periods or professional learning community meetings, teachers benefit from concentrated learning experiences that maximize their time and engagement (Hobson & McIntyre, 2016).

1.4 My Problem of Practice in Context

My place of practice is an underfunded urban school district in eastern Pennsylvania where STEM is not taught in elementary schools. My current institution is exploring STEM education, but it does not have a comprehensive STEM curriculum, pacing guide, or funding to support effective application of STEM instruction and pedagogical resources. My place of practice has made attempts to bridge the STEM instruction gap by purchasing "STEM kits" for its elementary school but often without a strategic plan for their use in the elementary education classrooms. My problem of practice (PoP) focuses on my role as a fourth-grade general education teacher and technology leader, aiming to integrate STEM within regular instructional topics. My research is informed by my problem of practice which is: School leaders use vital funding to purchase STEM materials but fail to provide effective STEM professional development to teachers, perpetuating

their lack of STEM self-efficacy. Limitation STEM education and professional learning supporting in elementary education is the impetus for my research inquiry situated in my place of practice.

This lack of STEM education presents several significant problems. Firstly, without STEM education, students miss out on developing critical thinking, problem-solving, and technological literacy skills essential in today's digital world. Additionally, students without a strong STEM foundation may struggle to compete in the job market, limiting their economic mobility and success. The absence of STEM education also exacerbates educational and economic disparities, particularly for underserved communities. A workforce lacking STEM skills limits regional economic development and competitiveness. Moreover, without engaging STEM opportunities, students may become disengaged from their overall education, leading to higher dropout rates and lower academic achievement.

For instance, the National Science Foundation (NSF) highlights that a strong foundation in STEM is critical for entry into a variety of STEM-related occupations and emphasizes the disparities in STEM achievement scores by socioeconomic status and race or ethnicity, which further contribute to economic and educational inequalities (NSF, 2023). Additionally, Brookings notes that the U.S. faces significant challenges in producing a sufficient number of skilled workers in STEM fields, with considerable implications for economic prosperity and national security (Brookings, 2023). HRForecast also underscores the global competition for STEM talent and the economic consequences of a workforce lacking in STEM skills, pointing out that countries with smaller pools of STEM talent struggle to fill critical positions, leading to skills shortages that hinder economic growth and innovation (HRForecast, 2023).

A key factor influencing this problem in my place of practice is the limited instructional time available in elementary schools, often dominated by English language arts and mathematics

due to standardized testing pressures. This intense focus on tested subjects marginalizes STEM education, which is not consistently supported with adequate time, resources, or teacher training. Elementary teachers are generalists expected to cover multiple subjects but may lack confidence and expertise in teaching STEM. This lack of confidence is compounded by teacher education programs that do not adequately prepare candidates for STEM instruction. Consequently, teachers often prioritize subjects they are more comfortable with, neglecting STEM education.

Through this exploratory inquiry, I aim to provide series of short exploratory "just-in-time" STEM professional learning sessions to elementary school teachers using STEM kits. This exploratory professional development approach explores how targeted interventions using STEM kits, can enhance educators' confidence in STEM instruction.

STEM kits play a pivotal role in these PD sessions by providing tangible resources that support hands-on learning experiences. These kits promote active exploration and experimentation, fostering a collaborative and inquiry-driven classroom environment. Incorporating these kits into PD sessions enhances teachers' pedagogical repertoire and cultivates a sense of efficacy in implementing STEM activities and fostering student engagement and achievement (Garet et al., 2001; Wessling & Howell, 2019).

Through my exploratory observational study, I designed and implemented short, focused PD sessions to elementary education teachers in my building to teach them how to use and integrate STEM kits in their current lesson planning. The short PD session provided teachers with targeted instruction on specific STEM topics, leveraging hands-on activities and collaborative learning experiences. I aimed to observe teachers' reactions to STEM instruction during and after the short STEM Kit PD. I also plan to offer and expand future STEM PD initiatives and strategies to support teachers in effectively integrating STEM across elementary school curricula.

1.5 Organizational System

My place of practice is set in Pennsylvania's fourth-largest urban public school district, located in the eastern part of the state. This district serves approximately 16,700 students from pre-kindergarten through grade 12 across 21 schools and 3 program sites. The district comprises three high schools, four middle schools, and fourteen elementary schools. It also includes an alternative school for grades 6-12 and two language support programs. The student population is 74% Hispanic, with 78% being economically disadvantaged.

My problem of practice centers around my institution’s efforts to implement STEM education in our district's elementary schools are not well planned, inconsistent and inequitable across grade levels. An example of this poor strategic planning concerning STEM is the school district use of grant funds to create a STEAM Leadership team. The team was task with identifying strengths in science education and prepare for the adoption of Next Generation Science Standards (NGSS), as well as provide professional development to teachers. However, since the pandemic, the team's progress stalled with no communication on future steps, resulting in sporadic STEM content integration. Another recent initiative emphasized the inequitable distribution of STEM resources involved the STREAM (Science, Technology, Reading, Engineering, Art, Mathematics) Academy. The district announced the opening of a STREAM, but the new initiative benefitted students in one out of the fourteen elementary schools (Pre-K–5th grade). These examples highlight the district's inconsistent approach to STEM integration, with efforts often limited to specific grade levels or schools. To foster a sustainable and equitable STEM education, the district should ensure consistent implementation across all elementary grades and provide ongoing professional development for teachers.

1.6 Inequitable Scheduling

In my place of practice, each building principal independently creates teacher schedules based on the school's needs, resulting in inconsistent and incoherent science curriculum implementation across elementary schools. For instance, one elementary school I worked at did not include Science and STEM in their daily schedule, citing satisfactory PSSA scores as justification. My elementary school allocates twenty-five minutes daily to science, while another school schedules twenty minutes at the end of the day. Some schools within our organization departmentalize upper elementary grades, typically dividing classes into ELA and math/science groups. In one instance, I experienced a unique three-way split with separate classes for math, ELA, and science/writing, although the focus remained predominantly on writing with limited time for science and STEM.

1.7 School District Key Values

At my place of practice in 2024, the school district's vision statement emphasizes preparing every student to thrive in a diverse and complex world with active community support. The district values include honoring each student's unique qualities, ensuring equity of access and opportunities, nurturing lifelong learning, strengthening partnerships with families and communities, promoting cultural responsiveness, and fostering trust and mutual respect. These values guide decision-making, shape the district's culture, and inform professional development initiatives. However, the inconsistent allocation of STEM resources, inadequate class time for

science and STEM instruction, and insufficient professional development opportunities do not align with these stated values.

1.8 My Positionality Statement

As an elementary educator, STEM enrichment teacher, STEAM leadership team member, and technology leader, my professional identity is deeply embedded in science education. My role spans traditional classrooms and specialized afterschool programs, allowing me to foster deeper engagement with STEM disciplines among diverse learners. My science identity and STEM expertise motivate me to teach STEM to elementary students and support teachers in this endeavor. I understand the transformative power of STEM education in shaping young minds and preparing them for the future. By connecting my science identity and research to my teaching practices, I aim to create a positive and lasting impact on students' educational journeys. I strive to inspire students to see the relevance and excitement of STEM in their everyday lives and future careers. Moreover, by supporting teachers, I hope to create a ripple effect that extends the reach and impact of quality STEM education, contributing to a more scientifically literate and technologically proficient society. As a technology leader, I advocate for STEM education in my school, and expand the boundaries of STEM to include the arts, recognizing the crucial role of creativity and innovation in scientific inquiry and technological advancement. I also champion the use of digital tools and resources to enhance educational experiences, ensuring both students and educators are proficient in the digital landscape.

My commitment to science education drives me to create inclusive and dynamic learning environments where every student can engage with and succeed in STEM fields. I am passionate

about providing quality and equitable professional development for my colleagues, equipping them to inspire the next generation of scientists, technologists, engineers, artists, and mathematicians. This dedication to fostering curiosity, critical thinking, and lifelong learning forms the foundation of my approach to STEM education.

1.9 District Theory of Action

A theory of action outlines the organization's beliefs about what will lead to long-term success and change. In my district, fostering a collective vision of exemplary learning and instruction, providing tailored resources and responsive partnerships to meet student and educator needs, ensuring consistent implementation, and delivering effective professional development and capacity-building practices are believed to reduce disparities in learning outcomes, accelerate progress, and improve academic achievement for all students.

1.10 Users/Concerned Parties

The K-12 educational system involves various stakeholders, but elementary schools are often excluded from discussions and decisions regarding funding allocation for STEM education, professional development, and class scheduling. Table 1 identifies stakeholders who are involved, impacted, or overlooked in addressing my problem of practice: school district leaders prioritize purchasing STEM materials for elementary schools but do not adequately support teachers with

effective STEM professional development, perpetuating low STEM self-efficacy among educators.

Table 1 Users & Concerned Parties

Involved Users	Impacted Users	Overlooked Users
Superintendent	Teachers	Teachers
Director of STEM	Students	Students
Director of Elementary Curriculum		Parents / Caregivers /Families
School Board		
STEAM Leadership Team		
Science Curriculum Team		
Principals		
Teachers		
Students		

1.10.1 School Board of Directors

The school board comprises elected officials with experience in nonprofit organizations within the urban community. They govern the school district, setting priorities for human resources and curriculum. Public comment during board meetings is limited to three minutes, often insufficient for meaningful discourse. The superintendent and upper administrators provide information for board consideration and decision-making. The school board significantly impacts teacher professional development by allocating resources, setting policies, and determining training priorities across the district.

1.10.2 Superintendent

The superintendent oversees school priorities and develops district-wide plans. They set the agenda for school board meetings and play a pivotal role in implementing professional development initiatives for teachers. By establishing district goals, allocating resources, and providing leadership, the superintendent influences the curriculum and instruction, professional learning programs that directly impacting teachers' growth and effectiveness.

1.10.3 Directors of STEM and Elementary Curriculum

Directors of STEM and elementary curriculum select science curricula and STEM materials for elementary schools and set schedules for teaching various subjects. While focusing primarily on mathematics education, they are also developing a new science curriculum and adopting Amplify Science K-8 for the 2024-2025 school year. These directors influence teacher professional development by designing specialized training and providing ongoing support to integrate STEM concepts effectively into the curriculum.

1.10.4 STEAM Leadership and Science Curriculum Teams

Comprised of elementary teachers, these teams advocate for STEM and science education but have limited authority in curriculum implementation or professional development. They play a minimal role in addressing the dissertation's problem of practice.

1.10.5 Principals

Principals manage daily operations and create schedules that directly impact how science and STEM are integrated into the school day. They influence the availability and focus of STEM professional development for teachers, making them crucial in addressing the dissertation's problem of practice.

1.10.6 Teachers

Teachers include classroom, related arts, learning support, ESOL, autistic support, and multiple disabilities teachers. They are directly impacted by administrative decisions on curriculum fidelity and daily schedules, influencing their ability to teach effectively. Teachers require adequate time and support to implement prescribed curricula. The deficit mindset among teachers, characterized by doubts about their own capabilities or inadequate professional development, poses a significant barrier to equitable and effective STEM integration across elementary schools.

1.10.7 Students

Students are involved and impacted by the limited science and STEM curriculum and instruction they receive, which varies across schools. Despite their enthusiasm for STEM, they often express frustration at the lack of time allocated for STEM learning activities, which affects their academic and professional opportunities.

1.10.8 Parents / Caregivers / Families

Parents, caregivers, and families at my place of practice are essential stakeholders who are involved, impacted, and often overlooked. They trust the school's curricular decisions but have limited opportunities to voice concerns about their children's education, including the minimal science and STEM instruction provided. As a result, they have minimal influence on my problem of practice, despite being directly affected by their children's STEM learning experiences.

1.11 Review of Supporting Literature

STEM education, as conceptualized by scholars at Mercy College, New York, integrates science, technology, engineering, and mathematics principles to cultivate critical thinking, problem-solving, and collaborative skills in students, preparing them for success in a technology-driven society (Marrero et al., 2014). Despite the push for integrating STEM education in K-12 classrooms, there remains a significant disparity in the professional development and resources available to elementary teachers. Resources supporting STEM integration are often concentrated in middle and high schools, leaving elementary educators without adequate training, support, and materials to effectively incorporate STEM into their curriculum. This deficit not only undermines teachers' confidence and proficiency in STEM instruction but also deprives students of crucial opportunities for hands-on learning and exploration.

Recognizing the importance of early exposure to STEM, the Quality National Council on Teachers (2023) emphasizes the need for elementary education to foster interest in engineering careers among women and minorities, highlighting the economic potential and demand for STEM

professionals. However, challenges persist in preparing teachers to effectively integrate STEM content due to limited professional development opportunities.

Maker-centered learning emerged as a promising approach to enhance the utilization of STEM kits in elementary classrooms. The maker movement provided formal and informal educators with pedagogical tools and strategies to support students' STEM learning experiences. This pedagogical approach engages students in interdisciplinary projects where they apply STEM concepts to solve real-world problems, fostering creativity, innovation, and personalized learning experiences tailored to students' interests. Teachers value how maker-centered activities promote collaboration, communication, and practical skills development, enhancing student engagement and learning outcomes. (Chambers & York, 2023)

The Maker Movement, characterized by its ethos of creating, sharing, experimenting, and innovating, presents a unique challenge and opportunity for K-12 education. However, institutionalizing making in formal educational settings faces obstacles such as standardization and the integration of maker activities within existing curriculum frameworks. These challenges underscore the need for further research and development to support the sustainable implementation of maker education in schools. (Chambers & York, 2023)

While STEM education lays the groundwork for maker activities, the Maker Movement's integration into educational settings requires addressing barriers and leveraging its potential to enrich student learning experiences. As educational reforms evolve, there is growing recognition of the interdisciplinary nature of learning through making, calling for a balanced approach that integrates STEM and the arts (STEAM) to foster holistic educational outcomes. (Project Zero, 2024)

1.11.1 Professional Learning and Development

My problem of practice entails investigating and addressing the lack of STEM instruction support that elementary school teachers receive to enable them to teach STEM concepts in their classrooms. This section of review of supporting literature explores the strategies that address my problem of practice. Choi and Ramsey (2010) found teachers are not prepared to utilize an inquiry-based teaching model and need additional professional development and exposure in pre-service teaching programs.

1.11.2 Pre-Service Programs

Elementary school teachers may not have experienced STEM education classes in their pre-service elementary teacher education programs to develop their confidence and ability to teach STEM. The absence of STEM education in pre-service teacher education programs poses several barriers to effectively teaching STEM subjects. A lack of pedagogical knowledge. Without exposure to STEM education during pre-service training, teachers may lack essential pedagogical knowledge and instructional strategies specific to teaching STEM subjects. Teachers who struggle to design inquiry-based lessons impact their ability to facilitate meaningful hands-on learning experiences to engage students effectively. York (2018) explained that "Increased exposure to inquiry-based STEM pedagogical practices during teacher preparation (specifically, instruction in pedagogical content knowledge, which includes methods and best practices specific to a particular subject area) has been linked to increased student achievement." (York, 2018).

Moreover, pre-service education offers limited STEM pedagogy content knowledge. In addition to the findings from the systematic review, the quote from Su Ling, Pang, & Lajium

(2020) underscores the importance of Pedagogical Content Knowledge (PCK) for teachers in facilitating successful STEM education outcomes for both teachers and students. PCK refers to teachers' understanding of how to effectively teach specific content knowledge to students. By increasing their PCK, teachers are better equipped to guide students in developing a strong conceptual understanding of STEM topics. This aligns with the notion that teacher professional development should not only focus on content knowledge but also on effective teaching strategies and approaches. By enhancing their PCK, teachers can create engaging and meaningful learning experiences that support students' conceptual development in STEM subjects, leading to improved academic outcomes.

Pre-service teachers who do not have pedagogy content knowledge in STEM subjects, can hinder their ability to teach these subjects effectively. “Our content knowledge affects how we interpret the content goals we are expected to reach with our students. It affects the way we hear and respond to our students and their questions. It affects our ability to explain clearly and to ask good questions.” (Lappan, 1999). Without a durable foundation in science, technology, engineering, and mathematics concepts, teachers continue to struggle to convey complex ideas and facilitate meaningful learning experiences for students.

Research, not confined to the United States but encompassing nations globally, consistently indicates a prevalent lack of confidence among elementary teachers when it comes to STEM instruction (Avery & Meyer, 2012; Flores, 2012; Nadelson et al., 2013). Elementary teachers' limited confidence in STEM is related to inadequate content knowledge (comprehension of STEM subjects) and pedagogical content knowledge (understanding of how to effectively teach STEM concepts) creating obstacles for teachers using dynamic and inquiry-based approaches in STEM education (Bencze, 2010; Walker, 2007). This trend may not be surprising given that elementary

educators often serve as generalists, being tasked, unrealistically, with mastering a wide range of subjects within their curriculum (Nelson & Landel, 2007). Enhancing Pedagogical Content Knowledge (PCK) for elementary teachers can be challenging due to their role as generalists. Elementary educators are often expected to teach a broad range of subjects, from language arts to mathematics to social studies, leaving limited time and resources for in-depth professional development in specific content areas like STEM. This expectation to master multiple subjects within their curriculum can be overwhelming and may lead to a lack of specialized training or expertise in STEM subjects. As a result, teachers may struggle to effectively integrate STEM education into their teaching practices, despite recognizing its importance for student learning and future success.

When teachers are supported in teaching STEM, it positively impacts their desire and confidence to teach the subject. Ippolito, Condie, Blanchette, & Cervoni (2018) discussed the benefits of extending professional learning opportunities for teachers on learning outcomes of students. The benefits include teachers continuing to value genuine opportunities to engage in integral professional learning opportunities as they continue to collaboratively examine problems of teaching pedagogy related to their instruction.

The systematic review of research, as described (Nadelson et, al. 2013), suggests that consistent and continuous professional development and support in STEM education contribute to increasing teachers' STEM knowledge and confidence. This support is crucial for enhancing teacher self-efficacy in STEM subjects. By providing ongoing professional development that includes pedagogical tools, teachers can develop the skills and confidence needed to effectively teach STEM subjects, leading to improved student academic success. Additionally, the variation among teachers' age, gender, experience, and perceived value of STEM education highlights the

importance of tailored support and training to address individual needs and preferences, further strengthening teacher self-efficacy in STEM education initiatives.

The National Research Council recommends that districts develop a mechanism for focused professional development that is coordinated and aligns with instructional reforms. The research of teacher's perceptions of stem integration, also concluded that teachers cited district support as the most crucial factor to STEM success in schools yet STEM professional development was the most mentioned topic in discussions. (Margot & Kettler, 2019). Various sources in STEM education literature do not provide a singular definition or model for integrating STEM in elementary education (Breiner et al., 2012; Roehrig et al., 2012; National Research Council, 2014). According to Johnson (2013), STEM integration involves merging science and mathematics teaching with the practices of scientific inquiry, technological and engineering design, mathematical analysis, and interdisciplinary skills (p. 367). The National Research Council's 2014 report, "STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research," offers a broader perspective, describing integrated STEM as encompassing diverse learning experiences that may span single class periods, entire curricula, specific courses, entire schools, or extracurricular activities (p. 39). A supportive administrative team is found to be important when implementing STEM pedagogy (Margot & Kettler, 2019). Teachers also communicated the need for flexibility and the expansion of the curricula to offer problems that meet the needs of student interactions and academic needs (Bruce-Davis, et al., 2014). Beyond the importance of flexibility and a solid support system, the K-12 curriculum framework should allow for STEM instruction (Herro & Quigley, 2017). Effective professional development would increase the effectiveness of STEM taught in classrooms and teachers to effectively integrate STEM into their curriculum (Bruce-Davis, et al., 2014). Teachers

communicated increases in their confidence, knowledge, and efficacy to teach STEM after participating in STEM-based professional development (Nadelson & Seifert, 2013).

A review of supporting literature shows that one way to support teachers is through meaningful and applicable professional development. Ippolito, Condie, Blanchette, & Cervoni, 2018) recommended a yearlong teaching through a summer professional development program. The program was broken into two tracks: a pre-program introduction and "daily ongoing collaborative refinement of teaching practices." (Ippolito et al., 2018). The professional development sessions are spread over the summer to tailor support for the upcoming school year. Teachers were introduced to the multimodal read-it, write-it, do-it, and talk-it pedagogical method created by Pearson, Moje and Greenleaf's (2010). The summer experience provided teachers with professional development experiences and opportunities to apply and use the knowledge and skills they acquired in their classrooms. This experience assisted in alleviating some of the invisible pressures that teachers feel when teaching STEM. The researchers found that the teacher-participants valued the experience and continued to seek out additional professional development opportunities that would expand their knowledge during this summer learning program. Teachers also shifted their focus in the classroom so that common planning time "focused explicitly on their students' scientific reading and writing as well as planning hands-on experiments." (Ippolito et al., 2018). Without much-needed professional development support and exposure to STEM including opportunities for feedback, and reflection, elementary teachers will continue to be unprepared to teach STEM in elementary classrooms.

In a similar study, Nadelson et al.'s (2013) program was a four-year-long professional development, with an annual 3-day summer institute. The professional development continued throughout the school year with on-site support and online modules. Throughout the professional

development, “participants were engaged in hands-on activities that exemplified best instructional practices and were models for teachers as they began to develop their lessons.” (Nadelson, et al., 2013) The focus on teaching teachers through practice and hands-on learning allows teachers to take what they have learned and apply it to their classrooms. An important takeaway that teachers who participated in the program communicated was the emphasis on inquiry learning within a limited instruction time allotment for STEM. The teachers noted the merits of learning how to teach STEM meaningfully under time constraints and acknowledged the importance of receiving feedback as they applied specific pedagogical strategies.

Estapa and Tank (2017) conducted a study centered on integrating STEM in elementary classrooms through a professional development (PD) approach focused on an engineering design challenge. Their conceptual framework blended two STEM frameworks: the first from Roehrig et al. (2012), emphasizing deepening student understanding, broadening exposure, and increasing interest in STEM disciplines; the second from Moore and Stohlmann (2014), advocating for engaging contexts, engineering design experiences, and student-centered pedagogies. The study aimed to align teachers' practices with the Next Generation Science Standards (NGSS).

The research highlighted challenges in integrating STEM content due to teachers limited disciplinary knowledge, especially in elementary settings (Sanders, 2008; Ejiwale, 2013). To address this, Estapa and Tank emphasized the importance of grounding teachers' understanding in key learning theories and pedagogical approaches (Kelley & Knowles, 2016). They underscored the need to develop teachers' beliefs and understanding of integrated STEM instruction to enhance implementation success (Roehrig et al., 2012). Their findings indicated that many participants viewed engineering content more as a skill than academic content, impacting the integration of science and mathematics. This perspective aligned with Carson and Campbell's (2007) findings on

increased problem-solving strategies but limited integration of engineering concepts in classroom practices.

Estapa and Tank emphasize that effective professional development (PD) for teachers should go beyond content knowledge to support the practical enactment of integrated STEM approaches. They advocate for incorporating rehearsal strategies, such as role-playing and microteaching, which allow teachers to practice and refine their instructional techniques in a controlled environment. This method helps teachers build confidence and competence in integrating STEM disciplines. Furthermore, they recommend modeling integrated connections within PD sessions to help teachers visualize and implement these strategies in their own classrooms, thus enhancing their overall effectiveness in teaching integrated STEM (Estapa & Tank, 2017; Grossman et al., 2009; Kazemi et al., 2016; McDonald et al., 2013).

Literature promotes professional learning, as a solution to assisting teachers in developing their STEM lessons. Another common theme that arises is that STEM instruction is inquiry-based. Inquiry-based learning does not equate to hands-on learning or experiments only, which is a misconception many teachers possess (Choi & Ramsey, 2010).

Significant resources have been dedicated to developing specialized knowledge in STEM professional development. However, many elementary teachers still do not feel prepared to integrate STEM into their classrooms (Corp et al., 2020; Shernoff et al., 2017) and do not identify as STEM teachers (Karaolis & Philippou, 2019). According to Wilson (2011), STEM professional development is often "short, fragmented, ineffective and not designed to meet the specific needs of individual teachers" (as cited in National Research Council, 2011, p. 21). This observation highlights the need to address contextual barriers to STEM integration, such as pedagogical challenges, structural issues, curriculum constraints, student readiness, and administrator support

(Ejiwale, 2013; Garcia-Carrillo et al., 2021; Margot & Keller, 2019; So et al., 2021). While addressing these barriers is crucial, it alone will not transform STEM integration at the elementary level. It is essential to focus not only on what teachers know and can do but also on their identity as it relates to integrated STEM and STEM teaching. As I look to the intervention, the most successful professional developments happen over longer periods of time, and to align with Wilson (2011) recommendations to tailor PD to meet the teachers' needs and professional goals.

1.11.3 Teacher Self-Efficacy

It is detrimental for elementary teachers to lack STEM self-efficacy for several reasons. It has an impact on teaching quality. STEM self-efficacy directly influences teachers' confidence and competence in teaching STEM subjects. When teachers lack confidence in their ability to teach STEM effectively, it can lead to decreased motivation, and reluctance to incorporate STEM activities into their lessons. The preparedness of elementary teachers to incorporate STEM concepts extends beyond mere disciplinary knowledge and pedagogical skills. Despite significant investments in enhancing this specialized expertise through STEM professional development, many elementary educators' express feelings of unpreparedness in integrating STEM content (Corp et al., 2020; Shernoff et al., 2017) and do not identify themselves as STEM instructors (Karaolis & Philippou, 2019).

Psychologist Albert Bandura characterizes self-efficacy as individuals' confidence in managing their actions and navigating life's circumstances. This belief serves as a cornerstone for motivation, satisfaction, and individual achievement. Self-efficacy stems from four main factors: (i) firsthand experiences of success, (ii) observing others' successes, (iii) encouragement from peers, and (iv) emotional states. Enhanced self-efficacy yields various advantages in everyday life,

including resilience against challenges, healthier lifestyle choices, heightened work productivity, and academic success. (Bandura, 1977). The elements comprising the integrated STEM teacher identity model are delineated below and depicted below in Figure 1.

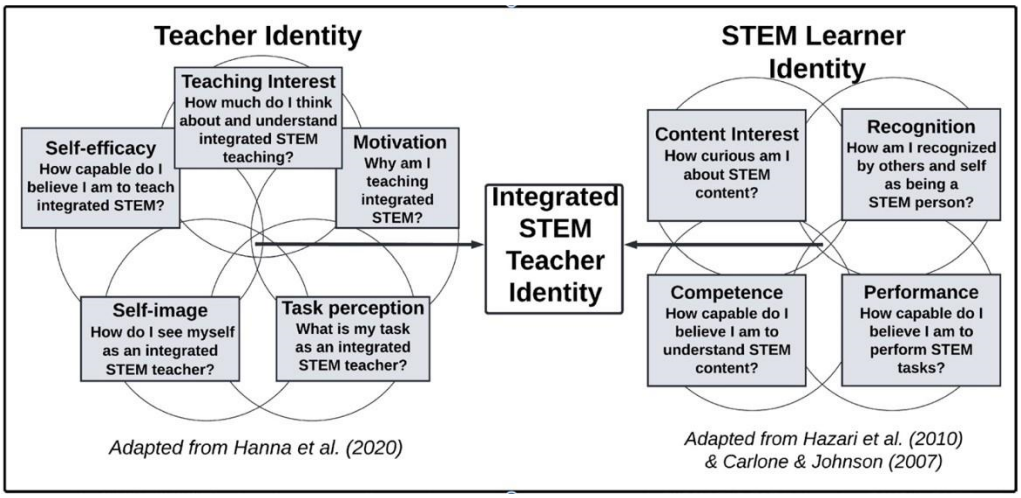


Figure 1 Integrated STEM teacher Identity Model

Teachers' beliefs about their own STEM abilities can impact student engagement and interest in STEM subjects. Students are more likely to be engaged and motivated when their teachers demonstrate confidence and enthusiasm for STEM learning. Many academic researchers propose that the beliefs held by teachers directly impact how they perceive and assess interactions related to learning and teaching in their classrooms. These beliefs subsequently shape their behaviors in the classroom (Clark & Peterson, 1986; Clark & Yinger, 1987). Furthermore, teacher beliefs can act as a "contextual filter," influencing how teachers view their classroom experiences and interpret their subsequent teaching practices (Clark & Peterson, 1986). Conversely, if teachers lack STEM self-efficacy, they may struggle to create engaging and interactive learning experiences for their students. Teachers with low STEM self-efficacy may be less likely to seek out or take

advantage of professional development opportunities related to STEM education. This can perpetuate a cycle of limited exposure to STEM pedagogy, resources, and best practices, further hindering teachers' ability to improve their STEM instruction over time. Low teacher self-efficacy has an Impact on student achievement. Research suggests that teachers' self-efficacy beliefs are correlated with student achievement outcomes. To be more precise, educators possessing greater levels of self-efficacy tend to persevere when encountering obstacles and are inclined to utilize a broader array of teaching methodologies. These approaches are potentially more adept at addressing the diverse challenges encountered within the classroom environment (Lauermann & ten Hagen, 2021). Therefore, when elementary teachers lack STEM self-efficacy, it can hurt student learning and academic performance in STEM subjects which is an education equity issue. All students, regardless of background or prior experiences, deserve access to high-quality STEM education. When teachers lack confidence in their ability to teach STEM effectively, it can exacerbate existing inequities in access to STEM learning opportunities and contribute to disparities in educational outcomes among student populations.

1.11.4 Stem Identity

Low STEM efficacy can hinder elementary educators from cultivating a robust STEM identity. Education and psychology research has established STEM (science, technology, engineering, and mathematics) identities as a principal factor in explaining student persistence in STEM fields. (Stewart, C. 2021) Societal stereotypes can negatively impact STEM identity. Stereotypes and societal perceptions about gender and STEM fields can influence teachers' beliefs about who is "naturally" good at STEM subjects. Teachers acknowledge that gender stereotypes are ingrained in social norms, subtly influencing their teaching practices. This can lead to self-

doubt and hinder their engagement with STEM, particularly if they perceive themselves as not conforming to the stereotype of a STEM professional. The study found consensus among participants regarding their knowledge of, confidence in, comfort with, and efficacy for teaching STEM content, suggesting that a lack of information may contribute to feelings of uncertainty about their abilities, resulting in reduced confidence, efficacy, and overall discomfort in teaching STEM concepts. (Zhou, Chhikara, Oudghiri, Osei-Tutu, & Dwomoh, 2023)

Previous research has traditionally conceptualized and operationalized STEM identities within individual disciplines (science, technology, engineering, and mathematics), primarily focusing on how undergraduate students perceive themselves as STEM individuals (Carlone & Johnson, 2007; Cribbs et al., 2015; Hazari et al., 2010). These existing measures of STEM identity are inadequate for studying elementary STEM teacher identity, as they are typically designed for emerging STEM professionals, who are not always categorized as elementary teachers.

1.11.5 Teacher Deficit Mindset

A teacher deficit mindset refers to an educator's perspective that emphasizes students' limitations or perceived deficiencies, particularly among those from marginalized or underrepresented backgrounds (Wake Technical Community College, 2021). This viewpoint attributes academic challenges to students' inherent abilities, socioeconomic status, family background, or cultural differences, rather than considering systemic issues, instructional strategies, or the educational environment. In the context of STEM teaching in elementary schools, a deficit mindset can have several negative implications:

Teachers with a deficit mindset may have lower expectations for their students' abilities in STEM subjects, leading to less challenging curricula, fewer opportunities for advanced learning,

and a lack of encouragement for students to pursue STEM-related activities and careers. If teachers do not believe in their students' potential to succeed in STEM, they may not invest in engaging and hands-on learning experiences. This can result in students becoming disengaged and disinterested in STEM subjects, further perpetuating the cycle of underachievement (Lombardi, J, 2016)

Teachers with a deficit mindset might not advocate for their students to have access to high-quality STEM resources, such as updated technology, science kits, and extracurricular programs. This inequitable access can hinder students' ability to fully engage with and excel in STEM education. Deficit thinking can influence how teachers assess and provide feedback to their students. They may interpret mistakes as a lack of ability rather than growth opportunities, which can discourage students from taking risks and developing a growth mindset (NWEA, 2023)

A deficit mindset can damage the teacher-student relationship, as students may sense that their teachers do not believe in their capabilities. This can reduce students' confidence, motivation, and willingness to participate in STEM activities. Teachers who hold a deficit mindset may be less likely to seek out or engage in professional development opportunities aimed at improving STEM teaching practices. This can prevent them from learning new, effective strategies that could benefit all students, particularly those from underrepresented groups.

A deficit mindset can reinforce harmful stereotypes about who can succeed in STEM fields. This can discourage girls, students of color, and those from low-income backgrounds from pursuing STEM subjects and careers, perpetuating underrepresentation in these fields.

Addressing a teacher deficit mindset involves promoting a growth mindset, where teachers view all students as capable of learning and excelling in STEM subjects with the right support and opportunities. Professional development that emphasizes culturally responsive teaching, equity in

education, and the importance of high expectations can help shift teacher perspectives. Additionally, providing teachers with the resources and support they need to implement effective STEM instruction can improve outcomes for all students. ISTE (2021) states, "The maker movement treats children as if they were competent. Too many schools do not."

There is not just one cause for the lack of STEM instruction in elementary schools. The enactment of school policy has unintended negative impacts on teacher preparation programs, out-of-school learning programs, school curricula, and professional development. The solution to the problem at hand is not easy and solving it for one building in my place of practice will not address the lack of STEM PD broadly across the elementary school system in my district, but it may provide a small agent of change that could begin to positively impact the school system.

As shown in the literature, both teacher preparation programs are deficient and professional developments in elementary instructional STEM. When teachers are afforded learning opportunities, they are more likely to teach what has been modeled for them based on what and how they were taught. If teachers are not confident in teaching STEM content using inquiry-based learning strategies, incorporating literacy instruction could be a solution to addressing this problem. The literature supports that reading strategies and scientific and literacy processing skills are closely aligned. The alignment allows for a natural flow of transdisciplinary instruction between literacy and STEM. Pearson, Moje, and Greenleaf (2010), believe a multimodal approach is an effective strategy for transdisciplinary STEM instruction. A transdisciplinary instructional to STEM Education involves teachers modeling connections between science, technology, engineering, and math processes, and concepts. Partnering with museums, local science centers, and scientists in the communities can provide learning opportunities for elementary school teachers and students to engage in hands-on STEM learning opportunities. Field trips allow

teachers to extend learning in the classroom, to prepare and prolong the field trip experience. A limitation to this approach is limited available funding and established partnerships to support hands-on informal STEM learning opportunities.

2.0 Theory of Improvement and Implementation Plan

My improvement theory and implementation plan will address an issue in my professional setting, where each elementary school building is furnished with STEM carts, yet teachers do not receive guidance and support to utilize these resources effectively with their students. My improvement theory comprises an overview of my aim statement, and the primary and secondary drivers that influence my proposed change strategies.

2.1 Driver-Diagram

In the elementary schools in my school district, teachers encounter numerous obstacles in enhancing their self-efficacy in STEM instruction. My theory of improvement aims to understand and mitigate the barriers experienced by K-5 teachers in my elementary school by providing STEM professional development to cultivate the K-5 teachers' STEM self-efficacy. Figure 1.6 illustrates the relations between the primary drivers, secondary drivers, and my change ideas. The drivers and change strategies that inform my theory of improvement and intervention are indicated in the pink text in Figure 2.

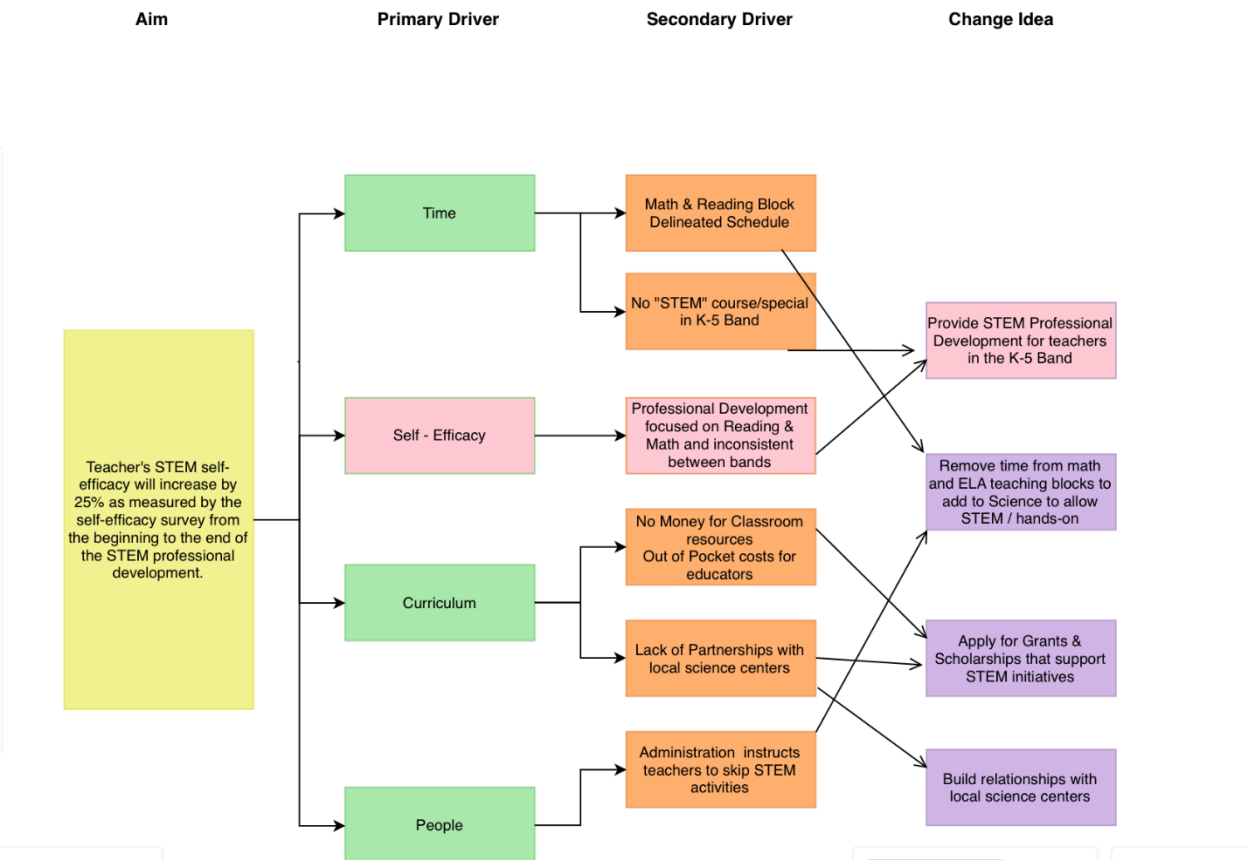


Figure 2 Drivers and Change Strategies

2.1.1 Aim Statement

My theory of improvement aim statement is by the end of the Pilot Exploration days teachers will be empowered to adopt a growth mindset implementing STEM cart items through targeted professional development with on-going support, which will lead to an increased in teacher confidence.

2.1.2 Drivers

In accordance with my proposed theory of improvement, four overarching primary drivers impact STEM self-efficacy among K-5 teachers. These drivers include time, self-efficacy, curriculum, and people, as detailed in the 'Primary Drivers' section of the Driver Diagram. These primary drivers represent configurations or methodologies within the system that can influence the overarching aim and theory of improvement.

Furthermore, my theory of improvement encompasses various secondary drivers, which serve as mechanisms for change aimed at addressing the primary drivers. These secondary drivers include time, curriculum, confidence, and school administrators, as outlined in the 'Secondary Drivers' section of the Driver Diagram. Each of these secondary drivers presents opportunities within the framework of each primary driver, where modifications or interventions may impact the overarching aim or theory of improvement.

2.1.2.1 Time

Educators require sufficient time to familiarize themselves with pedagogies and teaching practices. However, this proves challenging in elementary schools due to the absence of designated time for STEM teaching and learning. Instead, the instructional focus during the school day is primarily on enhancing students' reading and mathematics skills. In a typical six-hour school day totaling 360 minutes (about 6 hours), 160 minutes (about 2 and a half hours) are allocated for reading, 75 minutes for math, 30 minutes for lunch, 30 minutes for bathroom breaks, and 45 minutes for specials, leaving only 20 minutes for recess and science or STEM activities. This allocation does not include additional teacher contracted time before students arrive and during dismissal.

Two key factors exacerbate this challenge: the "Math and Reading Block Delineated Schedule" and the absence of specific STEM courses in K-5. These schedules limit opportunities for teachers to integrate STEM concepts into their classrooms. Consequently, the school's instructional schedule heavily emphasizes reading and math, with minimal time allocated to science instruction and social studies. Moreover, school policies regarding bathroom breaks often disrupt science instruction, particularly when it is scheduled at the end of the school day during dismissal.

Incorporating STEM concepts into other core subjects can increase STEM classroom time and be achieved through a variety of strategies. Strategies include interdisciplinary projects, hands-on activities, real-world applications, problem-based learning, and technology integration. In our pursuit of crafting a model for STEAM (Science, Technology, Engineering, Arts, and Mathematics) practices. Disciplinary integration encompasses interdisciplinary, multidisciplinary, and transdisciplinary approaches, each of which can be planned and implemented with varying degrees of success. I propose using an interdisciplinary STEAM pedagogical approach by facilitating the creation of authentic problems that align with curriculum objectives. This approach emphasizes effective problem-based instruction by providing opportunities for teachers and students to grapple with local issues with community members and partners in alignment with content areas. My proposed interdisciplinary pedagogical strategy leverages the expertise of community members, businesses, and non-profit organizations to STEM mentoring support for K-5 teachers. This approach also validates the relevance of real-world connections, acknowledging that solutions to complex problems often require collaboration among experts and seldom follow a single correct pathway. (Quigley, Herro, & Jamil, 2017)

To address these challenges, one potential strategy involves revising the elementary teaching schedule to prioritize science earlier in the day, making it more accessible. By reallocating 10 minutes from reading and math instruction, an additional 20 minutes could be devoted to inquiry-based STEM learning, thereby fostering a more balanced and equitable educational experience for students.

2.1.2.2 Self-efficacy

Teachers' confidence in delivering STEM lessons is based on their understanding of STEM practices and having opportunities to apply them in their elementary classrooms. Literature reviews highlight that teachers' limited knowledge of STEM teaching and learning also hinders their ability to effectively engage students in elementary STEM lessons.

A primary factor contributing to this challenge is the absence of STEM-focused professional development. Professional development plays a crucial role in enhancing teachers' self-efficacy to teach various subjects. In my elementary schools (K-5), professional development and support is concentrated on reading and math instructional strategies. However, these opportunities are inconsistent across grade bands, including K-2, 3-5, middle school, and high school. Without targeted STEM professional development, teachers lack the necessary skills and self-efficacy to effectively teach STEM concepts.

Hawe and Dixon (2017) highlight the crucial role of school leaders and professional learning facilitators in cultivating self-efficacious teachers, outlining six key criteria: 1. Developing a philosophical understanding of education, encompassing its goals, forms, methods, and significance; 2. Building pedagogical content knowledge, which involves integrating subject expertise with effective teaching methods; 3. Fostering teacher engagement from both teachers' and learners' perspectives, promoting active participation in learning and empathy for students'

learning experiences; 4. Encouraging reflection on learning within various contexts enables teachers to learn and adapt as both educators and learners; 5. Examining deep-seated beliefs and values that may influence daily actions and shape students' identities as learners, and 6. Enhancing teacher competence and confidence in implementing strategies to achieve positive outcomes for learners drawing on Bandura's four sources of efficacy: mastery experience, vicarious experience, social persuasion, and interpretation of physiological and emotional states. (Withy, 2019)

The secondary factors influencing self-efficacy include the absence of funding for additional classroom resources, leading teachers to personally finance materials such as folders, pencils, markers, and other essential supplies to facilitate hands-on STEM learning activities for their students. Given that teachers are already underpaid, it is unjust to expect them to bear the financial burden of purchasing resources out of pocket. Additionally, my elementary schools lack partnerships with local science centers, limiting access to supplementary resources in the classroom. Moreover, the scarcity of science centers in proximity to my professional setting, coupled with high demand from numerous school districts, strains the capacity of the nearby science center to collaborate with all interested schools due to insufficient grant funding.

2.1.3 Curriculum

The ELA and math curricula selected are rigid and do not facilitate the integration of STEM. Many commercially available curricula include STEM extensions along with support for English Language Learners (ELL) and a Multi-Tiered System of Support (MTSS). However, elementary teachers are mandated by the school district to adhere to the prescribed curriculum and pacing guide. Unfortunately, the structure of the curriculum does not accommodate inquiry-based

learning. This challenge is exacerbated by the school district's failure to choose and implement a dedicated science or STEM curriculum.

Consequently, the deficiency in STEM training and support materials may lead to incorrect delivery of STEM concepts or even the omission of STEM lessons altogether. Addressing this gap in professional development is essential to empower teachers with the knowledge and skills needed to confidently integrate STEM into their curriculum.

2.1.4 School Administrators

My school district has a directive to "Omit all STEM/hands-on learning activities." School administrators are disinclined to endorse activities that extend beyond the prescribed curriculum because excluding hands-on STEM and science learning allows for more instructional time dedicated to ELA and math. One strategy to address this issue could involve implementing an interdisciplinary instructional approach that supports and enhances ELA and math instruction within STEM lessons and extensions. The rationale behind this directive is to concentrate on math and reading to ensure students perform well on state standardized assessments. However, this overemphasis on standardized testing results in an unequal educational experience that overlooks meaningful science, STEM, and social studies learning for students. Another mitigating factor is that school administrators are overly focused on students' performance on standardized tests due to its impact on school funding. Recognizing the constraints of instructional time, school administrators and teachers can collaborate to devise innovative approaches to integrate STEM across math and reading content.

Addressing the challenges faced by K-5 teachers in enhancing their self-efficacy in STEM instruction requires a multifaceted approach. The primary drivers reflect barriers that impact

teachers' STEM self-efficacy include time, self-efficacy, curriculum, and school administrators. Additionally, secondary drivers such as funding constraints, lack of professional development, and rigid curricula further exacerbate these challenges. To overcome these barriers, strategies such as revising teaching schedules, providing targeted professional development, and implementing interdisciplinary instructional approaches are necessary.

Time constraints within the instructional day hinder the incorporation of STEM activities, emphasizing the need for restructuring schedules to prioritize STEM instruction. Additionally, addressing teachers' self-efficacy requires targeted professional development that focuses on building STEM skills and confidence. Moreover, the inflexible nature of curricula and directives from school administrators to prioritize ELA and math over STEM present significant hurdles that must be addressed through collaborative efforts between educators and administrators.

Prioritizing STEM education and integrating it seamlessly into the curriculum is essential for providing students with a well-rounded education that prepares them for success in an increasingly STEM-driven world. By addressing the primary and secondary drivers outlined in this analysis, educators can work towards fostering a culture of STEM excellence in elementary schools, ensuring that all students have access to high-quality STEM education.

2.1.5 Change Ideas

In this theory of improvement, three proposed changes aim to alleviate certain obstacles hindering the development of STEM self-efficacy among elementary school teachers.

2.1.6 Change Idea (A) - STEM Professional Development

My intervention entails implementing a change idea aimed at providing STEM professional development to teachers on how to integrate STEM resources in their elementary classrooms. The change I have chosen to implement is geared towards enhancing teachers' self-efficacy.

The professional development program is meticulously designed to broaden teachers' understanding of STEM pedagogy and practice, focusing specifically on how to incorporate and leverage STEM materials within their existing curriculum. To achieve this, I will develop STEM lessons that highlight the practical application of STEM items, allowing teachers to witness firsthand how these resources can be seamlessly integrated into their teaching methods.

The designed STEM lessons will adhere to Pearson, Moje & Greenleaf's (2010) multimodal pedagogical methodology, which emphasizes a comprehensive approach involving reading, writing, hands-on activities, and collaborative discussions. By incorporating this methodology, teachers will be equipped with diverse strategies to effectively implement STEM resources in their classrooms, fostering a deeper understanding and engagement among students.

Connecting STEM subjects is crucial for providing students with a rounded understanding of how these disciplines intersect and complement each other in real-world contexts. Here is how I might approach discussing the connections between each subject to support the understanding of the multimodal methodology for teachers during my professional development.

Science and mathematics are inherently intertwined, with mathematics serving as the language of science. In science, mathematical concepts such as measurement, data analysis, and geometric principles are essential for conducting experiments, analyzing results, and making predictions. Conversely, scientific inquiry often involves applying mathematical concepts and formulas to describe natural phenomena and solve problems.

The connections between science and reading are many and profound, as literacy skills are essential for understanding scientific concepts, conducting research, and communicating findings. Here are some ways in which science and reading are interconnected. Understanding scientific texts requires strong reading comprehension skills due to their complexity, including technical terminology and abstract concepts. Reading fosters analytical thinking, inference-making, and evidence-based conclusion drawing. In scientific research, reading is fundamental for accessing, evaluating, and synthesizing information from various sources, aiding students in conducting their investigations. Science literacy relies on robust vocabulary development, facilitated by exposure to specialized scientific terms and context-based learning activities. Different genres in science texts, such as informational texts and lab reports, familiarize students with scientific writing conventions, enhancing comprehension and communication of scientific information. Reading also facilitates cross-curricular connections, linking scientific concepts with other disciplines like mathematics and social studies. Moreover, reading aids in developing effective communication skills, crucial for presenting research findings and engaging in scientific discourse.

Mathematics and technology are closely intertwined in modern society, with technology often serving as a powerful tool for mathematical exploration and problem-solving. Digital tools and software programs enable students to visualize mathematical concepts, manipulate data, and explore mathematical relationships in ways that were not possible before. Additionally, technology plays a crucial role in applied mathematics, such as computer science and engineering, where mathematical concepts are used to develop algorithms, models, and simulations.

2.1.7 Change Idea (B): Science Teaching Block

The National Science Teaching Association recommends at least 60 minutes of science instruction per day in elementary schools alongside other core subjects (Schwartz, 2024). However, in my elementary school, teachers only have 20 minutes each day dedicated to science and STEM instruction. Additionally, a massive part of instructional time is distributed to over an hour of math instruction and 3 hours of reading. My proposed change ideas involve a slight adjustment to the schedule by reallocating 10 minutes from math and 20 minutes from reading to increase the time allocated for science instruction. This adjustment will provide teachers with ample time to actively engage students in STEM learning activities, potentially enhancing their confidence in teaching STEM subjects. I do not have the authority and agency to implement this change.

2.1.8 Change Idea (C) Grant Applications

One approach to tackle the issue of limited financial funding is for teachers to team up and jointly apply for grant funding aimed at acquiring STEM materials and resources. However, to effectively utilize these resources, teachers would need STEM professional development training. Securing grant funding has the potential to ignite teachers' interest in STEM education and inspire them to acquire the necessary skills to leverage these materials effectively in their classrooms. The grant application requires longer commitment outside this research inquiry's scope due to constraints of the doctoral program.

2.1.9 Change Idea (D) Establish Partnerships

Implementing this change idea to foster collaborations between local science centers and elementary schools would extend science and STEM instruction beyond the current 20-minute allocation. Welcoming science center staff into the classroom offers an opportunity for informal professional development for teachers, who can enhance their skills by seeing the science center staff deliver science and STEM instruction firsthand.

2.1.10 Inquiry Questions:

The inquiry questions will steer the Pilot Exploration days, while the iterations of the intervention will assist in assessing the influence of my STEM professional development initiative on enhancing elementary teachers' deficit mindset. This inquiry questions will shape my research inquiry and guide the analysis of data:

2.1.11 Research Inquiry Questions

The research inquiry questions list below will guide my exploratory observations is: How elementary teachers in my building interacted and reacted to the short ‘just-in-time” STEM kit professional development sessions provided to them?

2.1.12 Participants

Elementary teachers in my school took part in this exploratory observation research. I invited 27 teachers to participate in short STEM pilot exploratory workshops scheduled at the end of the academic school year. The teachers are white, 25 identified as females and two are males. A total of five teachers participated in the study, three took part in the formal PD STEM kit sessions and two teachers contacted me directly seeking support after learning about the sessions. The teachers who participated identified as female with teaching experience ranging from 18 to 25 years and one male with teaching experience of 20 years.

The table below provides an overview of the participants who took part in this observational inquiry.

Table 2 Participating Teachers

Teachers Pseudonym	Years of Teaching Experience	Experience with STEM Education and Kits
Mr. Jones	A white male with 20 years of teaching experience	No experience
Mrs. Dinkley	A white female with 18 years of teaching experience	No experience
Mrs. Blake	A white female with 19 years of teaching experience	No experience
Mrs. Rogers	A white female with 25 years of teaching experience	No experience
Mrs. Dewbert	A white female with 21 years of teaching experience	No experience

2.1.13 Research Inquiry Questions and Data Sources

Table 3: Inquiry Question

Inquiry Questions	Data Sources	Data Analysis Method
How did elementary teachers engage with and react to the STEM kits in the short 'just-in-time" STEM kit professional development sessions?	Researcher's detailed observation of teacher-participants engagement in the 'just-in-time' exploratory PD sessions Researcher's notes of interactions with teacher participants during and after the exploratory sessions.	Thematic analysis of observation notes Development of teacher cases

2.2 Intended Methods and Analyzes

I took detailed observational notes of teachers' behaviors, reactions, and comments during the short "just-in-time" exploratory sessions. I also took detailed notes of teachers' interactions with me relating to the STEM Kit after the PD sessions. I used thematic analysis to code my observation notes to gain insights into how teachers reacted to the PD sessions and their interest in integrating the STEM kits in the classroom in the upcoming academic year.

2.2.1 Method

I conducted an introductory exploratory pilot sessions to support elementary teachers in my place of practice to learn how to use different STEM kits and integrate them in their classrooms.

My objective for the initial exploration professional development sessions was to expose teachers to the STEM cart and kit to give them opportunities to play, tinker and explore the kits. By providing this PD to teachers, my hope is to increase their comfort level with handling and using different STEM kit resources and envision how they could integrate them in their lessons and classrooms.

I sent out the following invitation via (*see Figure 3*) to all contracted elementary teaching staff in my building during the last few weeks of the academic school year. I sent a google survey to teachers to ascertain their availability to attend my PD sessions. I offered the STEM kit exploratory sessions for two weeks during the teachers' morning preparation period between 8am and 8:30am. As part of the google form I listed all STEM cart items that teachers could engage with during the session which included Ozobots, Keva Planks, LEGO, K'nex, Beebot, Sphero Bolts, Cubetto, and Monoprice 3D printers. Three teachers attended the sessions, and I used pseudonyms to identify the teachers.

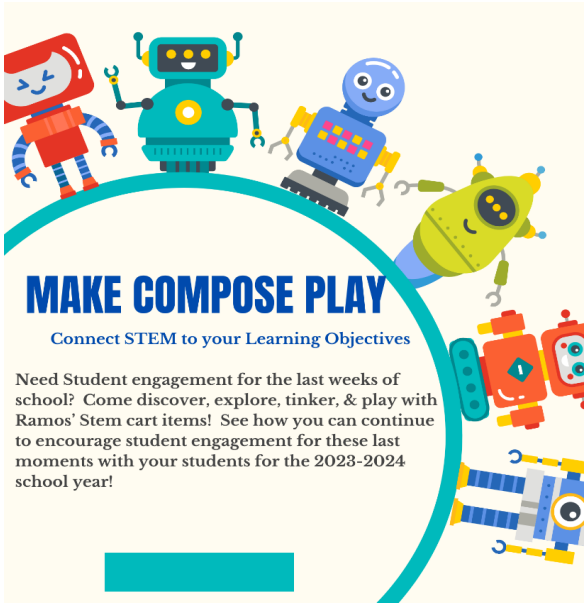


Figure 3 Invitation

I set up my classroom into stations based on the teachers' responses to the Google survey. I displayed the STEM items that connected to the teachers' professional interests and goals which aligned with Wilson's (2011) recommendation when designing PD experiences to align PD activities to teachers' needs and goals.

2.2.2 STEM Kit Station Descriptions

I used four of my student desks to make quadrilaterals for each station. **Station one** had Ozobots, white paper, markers, and coding sheets. **Station two** was set up with Keva Planks, the planks were spread around the table with a few pictures of designs they could emulate without being provided any words or instructions. **Station three** was a LEGO station. I had two different LEGO education kits, one being LEGO BricQ and other being LEGO Spike. I kept the LEGO in each respective containers with lids open and design booklets in front of them. **Station four** was BeeBot robots. This station included the bots and directionality cards. **Station five** was K'nex. In this station I had out the k'nex in their containers and I also included geometry-based pictures for teachers to interact with. Lastly, **station six** was Sphero Bolt which I placed on the table with corresponding iPads that were already open to Sphero.edu, which is the application necessary to code the robots.

Also available upon request are binders with lesson plans, I designed that correlate and correspond to grade level and Pennsylvania State Standards with each available item, as well as open invitations to join a Google Classroom, that I created, that contains even more lesson plans and resources that correlate to all available items.

2.3 Analysis Plan

I used a thematic and narrative analysis to code my observation of teachers' interactions and engagement during the Pilot Exploration sessions and tracking their subsequent use of STEM cart items in their classrooms. Throughout the professional development sessions, I took detailed observational notes to capture teachers' participation levels, behaviors, collaborations, and responses to the training materials. I paid special attention to how teachers communicated with each other and with me as the facilitator and observed their willingness to ask questions, and their enthusiasm in engaging with the STEM cart items. I also noted which teachers choose to take STEM cart items to try out in their classrooms. I encouraged teachers to share their experiences, challenges, and successes with the STEM items during follow-up sessions and took notes on these interactions. I generated case narratives based on my observation notes and analysis that involved identifying common themes and patterns. The narrative analysis of my observational notes provided insights into the factors that influence teachers' engagement with the STEM professional development and their willingness to integrate new resources into their teaching practice.

3.0 Results

During the STEM Kit Pilot Exploration sessions, several teachers interacted with STEM cart items to understand their reactions and engagement with the STEM kits and their interests in integrating the kits in their classrooms. The results sections are organized into 5 short teacher cases to describe their engagement with the STEM kits and interactions with their teachers and me during the PD.

3.1 Case One – Mr. Jones

Mr. Jones is a fourth-grade teacher who attended three consecutive sessions. Mr. Jones was the first teacher to attend, and the only teacher to attend more than one day. Initially, he expressed hesitation, saying, “Maybe I don’t want to do this today.” However, after some encouragement, he gravitated toward the LEGO station and began building, sharing his enthusiasm for LEGOs. His excitement grew as he learned about the potential of motorized parts for classroom use. By the end of the first day, his attitude had shifted from reluctance to enthusiasm, as he expressed his intention to explore more with a robot the next day.

Upon arriving in my classroom the next day, his eyes widened and appeared stunned to see all the items set up. Mr. Jones said, “Maybe, I don’t want to do this today.” I told him to take a walk around the room and look for something that calls out to him or makes him feel more comfortable. Mr. Jones gravitated toward the LEGO station and told me how he and his family put together LEGO kits all the time and how his ‘man cave’ has multiple LEGO shelves with his

favorite being the Captain America shield. Instead of looking at the designer booklets he just started to build. As he built, he asked questions once he got to the motorized parts in the kits, “Wait can these wheels actually drive like a remote-control car?”. I began to explain that there is Bluetooth capability between LEGO Spike and LEGO BricQ, however our district has it blocked as of now. It is something I am collaborating with the director of Stem to make available on all student and teacher devices. I continued to explain that I am hoping for the next school year that we will be able to utilize these LEGO kits to their full potential, since each teacher will be receiving one of each of the kits for their classrooms. Mr. Jones seemed extremely excited to have the availability of these LEGO kits in his classroom. Upon leaving for his first day Mr. Jones said, “I think tomorrow I will explore with an actual robot.”

On the second day, Mr. Jones returned to engage with the Ozobot station. He eagerly explored the Ozobot website for lesson plans, demonstrating a shift from a deficit mindset to a more proactive and confident approach. Mr. Jones picked up the robot and told me it reminded him of an android from Star-Wars. His first question was, “What can this guy do and how can I turn it on?” After demonstrating how to turn on the robot, showing him where the button was, and telling him how the robot ‘talks’ I told him to grab a piece of paper and a marker and draw a picture using the beveled edge of the marker. He asked me, “What kind of picture should I draw,” “What does this have to do with the robot?”, and “Why are there different colored markers with the robot?”. I told him all those questions would be answered in due time and repeated my direction to draw a picture. After some hesitation, he drew a house, and I told him to put the robot down on any of the lines of his home and to sit back and watch. As the robot followed the lines, Mr. Jones shouted, “How?” I picked up the robot and showed him the censor on the bottom of the robot and explained that one of the first ways I teach students to code is by drawing pictures. The robot will

follow any line, any color, but when you combine them in certain patterns the robot will do different things, rather than just follow a straight line. I showed him the coding reference guide so he could see all the different commands the robots will follow. I then asked him to code the robot to perform different tasks he saw on the sheet. I continued after a few minutes and asked him what ways he could see himself using these Ozobots in the classroom. His first response was, “I could definitely see me using these during math class when I’m teaching Geometry.” He continued by saying “I don’t necessarily know how I will tie together; do you have any suggestions?” I told him I do but I first wanted to show him a resource. I pulled up Ozobots website where they already have lesson plans and resources available for teachers. As he was leaving today, he said, “Those balls over there look interesting, that’s what I want to play with tomorrow.” His initial curiosity transformed into active experimentation as he learned to code the robot using drawings. This session highlighted his growing confidence and ability to see practical applications in teaching geometry.

In Mr. Jones’ final participation in the PD session, he went directly to the Sphero Bolts. This time he told me, “These look like the gyrospheres from Jurassic World”. Before I could answer him, he said, “Wait, aren’t these the robots you had your students present to the school board at the last meeting?” I answered him saying yes these are the same ones. I told him that I was going to show him and guide him through today’s exploration, compared to the last two days where you had more freedom to explore on your own. First thing I did was show him what the application on the iPad looked like and taught him how to pair the iPad to the Sphero Bolt. After pairing the robot and iPad, I showed him the simple drive feature that allows you to move the robot without any coding, similar to a remote-control car. After he drove the robot around the classroom, he commented how he could see students getting bored of that fairly quick and asked, “What else

can this do?". I showed him how to start a block coding session. I taught him the first four tabs of the coding page that included movements, lights, matrix, and sounds. I explained how for initial coding these will be more than enough to keep students engaged with the robot beyond the drive feature. I explain this is a very mathematical-based robot, starting with the movement aspect of the robot, it is based off degrees and angles. I showed him all the different light functions, the matrix functions, which includes being able to display words on the robot, and the sounds tab. Mr. Jones got super excited when hearing the robots talk and said, "The students know how much I love Transformers, this sounds exactly like Soundwave." He continued to say, "I can see how I can use this in math teaching angles, geometry, and even in Language arts, maybe for our spelling words." His most important words came as he left the classroom on his third day when he said, "I wish there was more time left in the school year so I could learn more and use these items more often."

The third day saw Mr. Jones exploring the Sphero Bolts, recognizing their educational potential for teaching angles, geometry, and spelling words. Guided through the app and basic coding functions, he quickly grasped the concepts and saw multiple ways to integrate these tools into his lessons. His growing excitement culminated in a wish for more time to further integrate these tools into his curriculum, showing a significant increase in confidence and enthusiasm for STEM integration.

3.2 Case Two: Mrs. Dinkley

Mrs. Dinkley, a fifth-grade teacher, rushed into my classroom because she was late and told me she was sorry, she was running late from a meeting. Upon catching her breath, she quickly

took in the classroom and station set up. She did not say a word and just walked over to the LEGO station. As she inspected the kits, she asked about the motors she saw, and I explained how the lego functioned. She nodded quickly, and said, “since I’m a self-declared LEGO expert, having completed many kits and sets at home, I’d like to learn about those,” and pointed to the Ozobots. She continued to talk about how she felt overwhelmed about the upcoming school year and how we are starting four new curriculums and asked for ways to incorporate STEM activities into those curriculums. I looked at the time and I explained to her that we do not have enough time to get into details of full curriculum incorporation, however I would be happy to show her the basics of Ozobots. With time limited to 10 minutes I walked her through how to turn on the robot, draw lines, and use the coding sheets. Mrs. Dinkley thanked me and asked if we had enough Ozobots for a class or if she had to place students in small teams. I informed her there is enough for a class set. She walked out and said she would be back to check them out and use them in her classroom before the end of the year. This was the only day Mrs. Dinkley attended the learning sessions.

Despite feeling overwhelmed by the upcoming school year, Mrs. Dinkley quickly learned the basics of the Ozobots and expressed a desire to incorporate STEM activities into her lessons. Her brief but productive session highlighted a positive change in attitude and a willingness to learn despite time constraints.

3.3 Case Three – Mrs. Blake

Mrs. Blake, a second-grade teacher, entered hesitantly, concerned about her students' ability to handle the STEM items. Mrs. Blake attended the learning session today; she is a second-grade teacher. Mrs. Blake was very hesitant to enter the room, but she entered and sat down on a

chair, on her hands and said, “I just don’t want my students to break them!”. She followed that comment up with, “I’m not sure my students will be able to do any of this.” This is an example of a deficit mindset. I first explained that if she is concerned about the items breaking, that they were not purchased by me, that they were purchased by the district for every elementary school. She was shocked to hear that and said, “Oh I wasn’t aware.” I asked her how many students in her class participated in the after-school program and she told me she had quite a few, so I recommended having her use those students as leaders and mentors for the rest of the class since those students in the after-school program have all been successfully using the STEM items with me already, since the beginning of the school year. I told her she could consider them experts and she liked that idea that she would have helpers already in the classroom and she began verbally making plans of who would lead the groups. I briefly showed her Ozobots and asked her if she wanted to try it and she quickly shook her head and said ‘no’. I asked her what she was currently teaching in her classroom, and she said, “pollination.” So, I suggested that she could replicate how bees and butterflies move from flower to flower using the Ozobots to mimic the process of pollination. She appeared excited and said, “That sounds like a really cool idea, and I think my students will be excited to use those robots to show what they know as an exit ticket to demonstrate the process of pollination.” She also asked if we had enough Ozobots for the whole class if she wanted to try them out. She also said, “I think I will be back to get the set before the end of the year.” And she left my room.

Her initial comments, “I just don’t want my students to break them!” and “I’m not sure my students will be able to do any of this,” reflected a deficit mindset. However, after reassurance and suggestions on leveraging students in the after-school program as mentors, she became more open

to using the Ozobots. Her excitement grew as she saw the potential for these tools to enhance her lessons on pollination, indicating a positive shift in attitude and confidence.

3.4 Case Four – Mrs. Rogers

Mrs. Rogers is an Autistic Support Teacher who ran into my classroom one day unexpected and exclaimed, “I did not fill out your survey, I did not respond to anything you sent out, but I am very interested in the items that you believe could be used in an Autistic Support classroom.” She continued, “I don’t have a lot of time today, can you explain something in five minutes or less.” I pulled out Keva planks and explained the uniqueness of the designs behind Keeva and explained how students can build two and three-dimensional objects, using their own imagination, or they can follow any of the pictures and try to emulate it without written instructions. Mrs. Rogers commented how they already have building blocks in the classroom that are thicker, and these Keva planks can be more of a challenge for her students.” I explained that one of her students attends the after-school program and has already interacted with all STEM items with me so that student could also be used as a resource and mentor for the other students. She said, “Oh, I really like this idea and I’ll be back.” The next day she came in to grab the Keva planks and at the end of the day had sent me videos of her students engaging with the Keva planks and explained how she went from self-exploration to showing them pictures for them to replicate to incorporating them into her science lesson by having them make a flower and explain the different parts of the flower. She also took notice that her verbal, more high functioning students, built in full three dimensions and her lower functioning, non-verbal students build in two dimensional. She said she would be interested to see if there is any research that backed what she noticed in the classroom

with the design choices or if it was just coincidence. She told me how eye-opening this experience was and that she was excited about next school year and learning about more of the STEM items and incorporating them into her students learning. Mrs. Rogers initially skeptical, quickly saw the potential of Keva planks for her students. Her follow-up with videos of her students' interactions underscored the immediate positive impact of the STEM items and her growing enthusiasm for further integration, demonstrating a meaningful change in attitude and confidence.

Overall, the teacher cases highlighted the pivotal role a brief exploratory just-in-time PD session with teachers helped to develop participants' interests and confidence levels using different STEM kits. The brief hands-on exploration, targeted support, and peer mentorship teacher-participants received helped to foster a growth mindset among teachers.

3.5 Case five – Mrs. Dewbert

Mrs. Dewbert, another fourth-grade teacher who did not attend any of my professional development days, was initially reluctant, believing her students couldn't handle the Ozobots. Her initial refusal, "No, absolutely not. I can't do this, my students won't be able to do this," highlighted a strong deficit mindset. However, she was convinced to use Ozobots with her students who had been struggling behaviorally. I was able to ease Mrs. Dewbert's reluctance by suggesting her students who have experience with Ozobots guide other students. To lessen the hesitancy, I set up the Ozobot coding guide, the paper, markers, and robots. The success of this session was evident in her excitement and pride in her students' achievements, demonstrating a transformative change in attitude and confidence in her students' abilities.

3.6 Findings - Summary of Analyses of Teacher Cases

The summary attempts to answer the inquiry Question: How did elementary teachers engage with and react to the STEM kits in the short 'just-in-time" STEM kit professional development sessions? Participants initially approached the STEM Kit professional development with varying levels of reluctance. However, through structured sessions, they progressively engaged with and explored the potential of STEM tools such as LEGOs, Ozobots, and Sphero Bolts. Teachers like Mr. Jones and Mrs. Blake exemplified this transformation, evolving from initial skepticism to enthusiastic adoption of these educational resources. For Mr. Jones, his childhood affinity for toys like the LEGO kits facilitated a natural connection and rekindled enthusiasm, ultimately boosting his confidence in integrating these tools across different subject areas. Similarly, Mrs. Blake's concerns about her students' abilities were addressed through practical suggestions and peer mentorship, leading her to envision innovative uses of Ozobots in teaching pollination concepts.

Conversely, Mrs. Dinkley initially expressed deficit thinking regarding her students' readiness for STEM activities and exhibited apprehension about incorporating new resources into her teaching. However, exposure to the basics of Ozobots during the PD session hinted at a gradual shift in her perceptions, hinting at a potential for future integration.

Furthermore, Mrs. Rogers and Mrs. Dewbert, initially skeptical of their students' capabilities, experienced transformative moments during the sessions. Mrs. Rogers swiftly integrated Keva planks into her Autistic Support classroom after witnessing their immediate impact on student engagement and learning. Conversely, Mrs. Dewbert's reservations about her students' proficiency with Ozobots were dispelled when she observed their unexpected success with the coding tasks, prompting a reassessment of their potential.

In sum, the analysis of these teacher cases highlights a notable progression from initial reluctance and skepticism to active engagement and enthusiasm for STEM integration. These transformations underscore the empowering role of professional development in equipping teachers with the confidence and skills to leverage innovative tools effectively in their classrooms. The findings underscore the need for continued support and resources to sustain and deepen these positive changes, ultimately enhancing educational practices and student learning outcomes.

4.0 Learning & Actions

4.1 Discussion

The findings from the Teacher Cases shed light on several critical aspects relevant to the problem of practice in my place of practice regarding STEM integration. I

One key finding was the transformative impact of hands-on exploration and guided support on teacher attitudes and confidence levels. Teachers like Mr. Jones and Mrs. Blake, after engaging with STEM cart items such as LEGOs, Ozobots, and Sphero Bolts, exhibited increased enthusiasm and confidence in integrating these tools into their classrooms. This shift suggests that targeted professional development and practical exposure can effectively mitigate the lack of STEM self-efficacy among educators (Darling-Hammond et al., 2017).

Additionally, the teacher cases also highlighted systemic barriers that contribute to the perpetuation of teacher hesitancy and lack of efficacy. These include inadequate time allocated for professional development, limited administrative support for STEM initiatives, and scheduling conflicts that restrict teachers' ability to fully engage with STEM activities (Hirsch, 2016). Such systemic challenges underscore the need for systemic change within educational institutions to prioritize ongoing and meaningful professional development that aligns with the acquisition and implementation of new instructional strategies (Wei et al., 2018).

Notably, the limited duration and scope of the exploratory professional development sessions may have constrained the depth of teacher engagement. Ongoing and comprehensive professional development is essential to sustain and deepen the transformative impact of STEM integration efforts (Garet et al., 2001).

In the context of this research, it is worth mentioning that the teachers who participated in the professional development and were willing to incorporate STEM kit items into their teaching routines were all tenured educators with over 15 years of experience. This finding highlights a broader trend observed among experienced teachers: a hesitation and reluctance to adopt new methodologies or integrate new materials into their established routines. This reluctance may stem from the comfort and familiarity they have developed with their long-standing practices and the expectations they have set for themselves. Despite their extensive experience, the introduction of new concepts, such as STEM, can still present a daunting challenge for these seasoned educators. This occurrence highlights the need for directed support and strategies to encourage veteran teachers to embrace innovative teaching practices, ensuring that their wealth of experience can be effectively leveraged to enhance STEM education.

Research supports this idea of reluctance among experienced teachers. Fullan (2001) suggests that experienced teachers can be resistant to change due to established routines and comfort with existing practices. They may perceive new initiatives as a threat to their professional identity and autonomy. Day and Gu (2007) highlight that veteran teachers develop a strong sense of efficacy and comfort with their teaching methods over time, which can make them less inclined to adopt new and unfamiliar teaching strategies. Guskey (2002) indicates that professional development programs need to be specifically designed to address the concerns and needs of experienced teachers; without targeted support, these educators may be less likely to implement new instructional approaches. Evers, Brouwers, and Tomic (2002) found that experienced teachers may fear the uncertainty and potential failure associated with trying new methods, leading to reluctance in adopting innovative practices, including STEM education. Studies by Borko (2004) and Penuel et al. (2007) show that teachers are more likely to embrace new teaching methods if

they perceive them as relevant and practical for their specific classroom contexts, but experienced teachers may be skeptical about the applicability of new approaches, further contributing to their reluctance. The findings accentuate the critical role of targeted professional development and supportive systems in addressing the problem of practice regarding STEM integration in elementary schools. Moving forward, it is imperative for school leaders and policymakers to allocate sufficient resources and time for professional learning that builds teachers' STEM self-efficacy and addresses systemic barriers. This approach not only enhances teacher confidence and competence in STEM instruction but also contributes to improved student outcomes and prepares them for success in a rapidly evolving world.

4.2 Next Steps and Implications

The next steps are to offer extended exploratory PD STEM sessions that meet teachers' learning needs and give them ample time to overcome their initial fears, explore the STEM kit and consider with their colleagues how to incorporate them in their lesson planning and classroom activities.

It is essential to advocate for ongoing and differentiated professional development tailored to meet the varying needs of educators, addressing both content knowledge and pedagogical strategies in STEM education. This can include longer-term workshops, coaching sessions, and collaborative planning opportunities that support teachers in integrating STEM tools into their curriculum effectively (Darling-Hammond et al., 2017).

School leaders should prioritize the allocation of resources, including time and funding, to support sustained implementation of STEM initiatives. This involves revisiting scheduling

practices to ensure adequate time for STEM instruction and professional development, as well as securing necessary equipment and materials to maintain engagement and enthusiasm among teachers and students alike (Garet et al., 2001).

Moreover, fostering a culture of collaboration and sharing best practices among educators is crucial for sustaining change. Establishing communities of practice or peer learning networks can facilitate ongoing support and knowledge exchange, encouraging continuous improvement in STEM teaching practices (Wei et al., 2009).

Lessons learned from this initiative highlight the transformative potential of hands-on, experiential learning in overcoming initial hesitancy and building confidence among educators in STEM instruction. By addressing systemic barriers and providing meaningful professional development opportunities, schools can enhance teacher efficacy and ultimately improve student outcomes in STEM education (Liu & Bera, 2016).

Implications for practice emphasize the importance of aligning professional development with educational goals and fostering a supportive environment that values innovation and continuous learning. Education systems should prioritize flexibility and responsiveness to teacher needs, ensuring that resources are allocated effectively to sustain improvements in STEM education across diverse school settings (Hirsch, 2016).

For further research, exploring longitudinal impacts of sustained professional development on teacher practice and student achievement in STEM subjects would provide valuable insights into effective strategies for scaling and institutionalizing STEM initiatives. Additionally, investigating the role of leadership and policy in supporting STEM integration at both local and national levels could inform policy recommendations aimed at fostering a more robust and equitable STEM education ecosystem.

In conclusion, by building on the successes and addressing the challenges identified through narrative analysis, schools can take proactive steps towards cultivating a culture of STEM excellence that prepares students for future success in a rapidly evolving global landscape.

5.0 Reflections

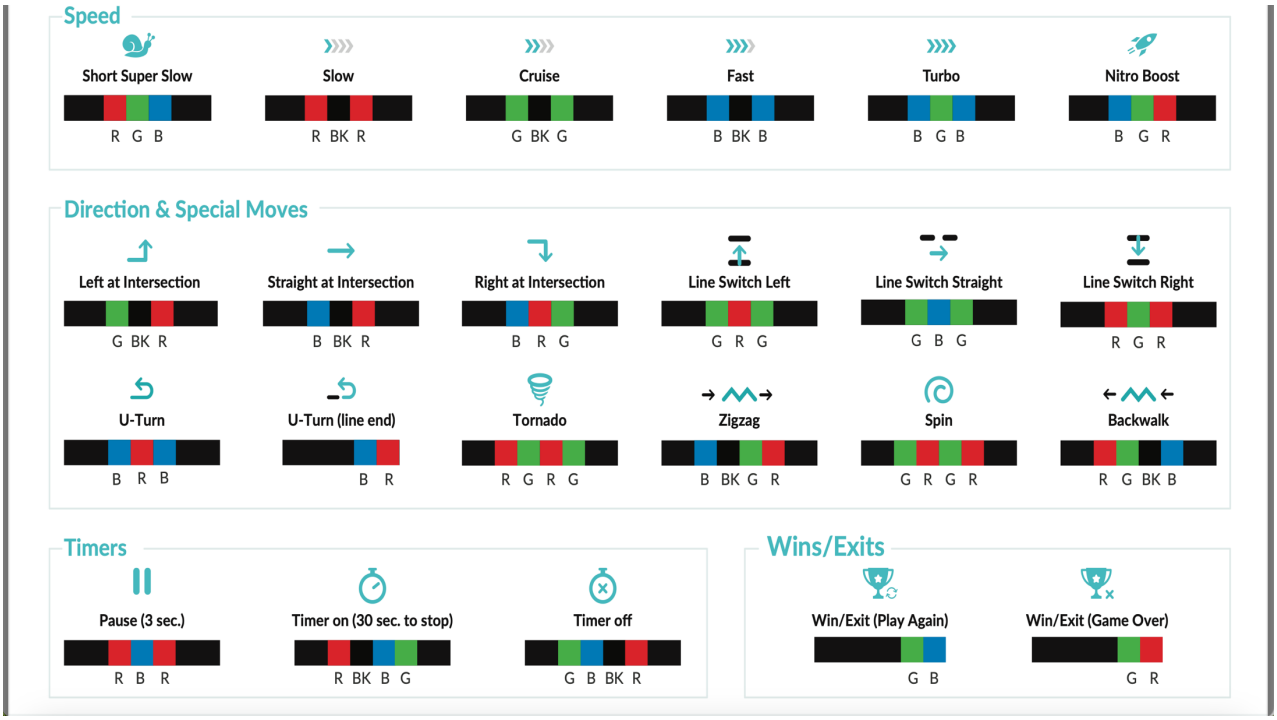
Reflecting on this journey of initiating and leading the STEM integration pilot, several key insights have emerged regarding improvement, leadership, and my role as a school practitioner. Firstly, I've learned that improvement in educational settings requires a multifaceted approach that goes beyond mere resource allocation. Effective change hinges on addressing systemic challenges such as inadequate professional development and time constraints, which directly impact teacher efficacy and student engagement in STEM subjects. This experience underscored the importance of collaborative leadership and strategic planning in navigating organizational complexities and fostering sustainable change (Bryk et al., 2015).

Personally, I've grown in my understanding of myself as an improver and leader within the school context. I've come to appreciate the value of perseverance and adaptability in overcoming resistance and fostering a culture of innovation. As an improver, I've learned to prioritize listening to stakeholders, understanding their needs, and co-designing solutions that resonate with the broader educational goals and aspirations of the community. This reflective process has deepened my commitment to continuous improvement and lifelong learning, recognizing that meaningful change requires ongoing reflection, refinement, and adaptation of strategies (Senge et al., 2012).

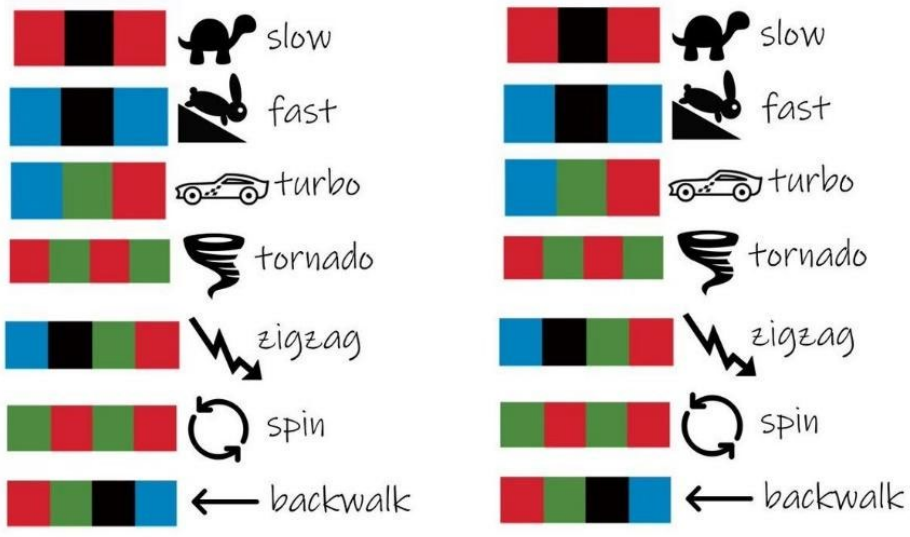
Looking ahead, I intend to apply these insights and methodologies to other problems of practice as a scholarly practitioner in education. I aim to leverage evidence-based practices and data-driven decision-making to inform future initiatives, ensuring that improvement efforts are grounded in research and tailored to address specific challenges within educational contexts. By cultivating a culture of inquiry and collaboration, I seek to empower educators and stakeholders to co-create solutions that enhance teaching and learning outcomes across diverse settings.

This experience has reinforced my belief in the transformative power of strategic improvement efforts and collaborative leadership in driving educational change. As I continue to advance in my professional journey, I am committed to advocating for equitable access to quality STEM education and fostering a supportive environment where all learners can thrive and succeed.

Appendix



Appendix Figure 1: Ozobot Code Sheet



Appendix Figure 2: Ozobot Code Sheet

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