"Teachers in the Workforce" Grant Intervention: Effective Professional Development for

STEAM Integration and Career Standards Implementation

by

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University of Pittsburgh, 2021

Science, technology, engineering, and mathematics, often referred to as STEM, have been the cornerstone for American success through innovation and entrepreneurialism. Concerns for economic prosperity and national security, as well as a concern for creating a technological and scientifically literate society, have created tremendous support for STEM education at the federal, state, and local levels. Despite this trend, jobs in STEM fields continue to go unfilled and are disproportionately underrepresented by minoritized groups. Recently, STEM has been expanded to STEAM, (Science, Technology, Engineering, Arts, and Math), presumably to widen the appeal of STEM subjects by including an emphasis on the arts and creative expression (Herro & Quigley, 2019; Johnson, 2014). STEAM is a transdisciplinary approach that applies academic concepts to a consideration of real-world issues as a catalyst to teach academic concepts, communications skills, and critical thinking while building soft skills such as cooperation, adaptability, and creativity. A rising tide among educators and other stakeholders is building momentum for the changes in methods, materials, and instructional practices required for STEAM pedagogy to take root. Ultimately, this practice must be implemented at the micro-level, in classrooms with teachers and students. How can schools prepare educators to make this change? This study will investigate the effectiveness of a professional development intervention to support teachers as they develop lesson plans that integrate STEAM pedagogy and career readiness, focusing on the process skills

required for success in a changing work environment. The study was conducted in a small suburban school district. A small group of K-12 teachers participated in a virtual professional learning experience that included interactions with professionals working in STEAM fields. Changes in understanding, attitudes, and feelings of efficacy were analyzed through a mixed-methods approach and reported using quantitative and qualitative data to inform future PD experiences within the district. The study found that although teachers reported a change in their sense of efficacy, this change was not reflected in their lesson planning documents. Data indicated the need for more support, such as samples, testimonials, and collaborative experiences, for classroom teachers to successfully develop STEAM-based curriculum units.

Table of Contents

Acknowledgements xi
1.0 Introduction and Rationale1
1.1 The System
1.2 Stakeholders7
1.3 Problem of Practice 15
2.0 Review of Supporting Knowledge
2.1 Introduction
2.2 Professional Development Models in STEM and STEAM 23
2.3 Effective Online Professional Development
3.0 Methodology
3.1 Theory of Improvement
3.2 Drivers and Driver Diagram
3.3 Change Idea and Intervention Overview
3.4 Research Questions
3.5 Plan-Do-Study-Act Cycle 44
3.6 Methods and Measures 44
3.6.1 Surveys
3.6.2 Artifact Analysis50
3.6.3 Interviews and Open-ended Survey Responses51
4.0 PDSA Results
4.1 Data Collection

4.1.1 Participant Data	57
4.2 Research Question 1: Effects on Teacher Efficacy	62
4.2.1 Survey Data	62
4.2.2 Teacher Interviews	64
4.2.3 Summary	66
4.3 Research Question 2: Lesson Plan Analysis Data	67
4.3.1 Problem Scenario	68
4.3.2 Discipline Integration	69
4.3.3 Career Standard Integration	69
4.3.4 Technology Integration	70
4.3.5 Authentic Task Integration	71
4.3.6 Opportunities for Student Choice	71
4.3.7 Lesson Plan Analysis Summary	72
4.4 Research Question 3: Additional Supports Needed for Implementation	73
4.4.1 Open-ended Survey Data	73
4.4.2 Interview Data	75
4.4.3 Summary	77
5.0 Discussion	
5.1 Mitigating Factors	
5.2 Effects on Efficacy	80
5.3 Lesson Plan Integration	82
5.4 Additional Supports	83
5.4.1 Deeper Conceptualization	83

5.4.2 Just in Time Feedback	84
5.4.3 Administrative Support	86
6.0 Reflection	
6.1 Contextual Factors Influencing STEAM Integration	
6.2 Study Limitations and Implications	
6.3 Recommendations and Next Steps	
Appendix A Document Analysis	
Appendix B PDSA Cycle	
Appendix C Professional Development Agendas	
Appendix D Teachers in the Workforce PD Pre-survey	
Appendix E Teachers in the Workforce PD Post-survey	111
Appendix F STEAM DESIGN Unit Plan Rubric	122
Appendix G STEAM DESIGN Analysis and Descriptors	125
Bibliography	

List of Tables

Table 1. RSD Demographics	9
Table 2. Overview of Professional Development Intervention	40
Table 3. Changes, Data, and Measures	46
Table 4. Triangulation Matrix	48
Table 5. Lesson Plan Analysis Categories	51
Table 6. Interview Question Correlation	53
Table 7. Teaching Experience of Pre- and Post-survey Participants	57
Table 8. Education Levels of Participants	58
Table 9. Prior STEAM PD Experiences	61
Table 10. Pre- and Post-survey Comparison	63
Table 11. Lesson Plan Analysis Quantitative Summary N=9	68
Table 12. Thematic Coding of Open-Ended Survey Responses	74
Table 13. Thematic Coding of Interview Responses	76
Table 14. Implications for Future Research	

List of Figures

Figure 1. Fishbone Analysis of Factors Influencing RSD STEAM Integration11
Figure 2. Force Field Analysis of Factors Supporting and Deterring STEAM Integration 15
Figure 3. Driver Diagram
Figure 4. Content Areas Taught by Participants

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me. Watching you "fly" in this rapidly changing world inspires me to continue striving to be the teacher you deserve and empowering my colleagues to do the same.

1.0 Introduction and Rationale

It is difficult to deny the importance of STEM literacy for individuals to operate successfully in the 21st-century workforce and participate meaningfully in society at large. Informed citizens must be capable of functioning in a world that is increasingly driven by advances in technology and should think critically in order to sift through abundant sources of information. Unfortunately, the prevalent pedagogy that dominates classroom activities tends to establish the teacher as the importer of content knowledge and students as passive recipients, a model that is insufficient to prepare students for the demands of a changing and globalized world. Fortunately, there is a movement towards a major modification of the methods and materials currently employed in classroom settings. A report by UNESCO (the United Nations Educational, Scientific and Cultural Organization) (Scott, 2015) addresses the need for a paradigm shift required to prepare learners for the changing needs of the 21st-century workplace. The author argues for the development of new pedagogy that will change the focus of classroom activities to include more collaboration, problem-solving, communication, opportunities for individualized autonomous learning, constructivist activities, and the use of relevant technology. This impetus for change is often labeled STEM education.

STEM is a conglomerate term used to describe general policies at the state and national levels, but it does not give clear parameters for school programs and implications for instructional practices (Bybee, 2013). Past federal and state policy documents reflected an interest in promoting STEM education in K-12 educational contexts (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010; National Research Council, 2011, 2013). President Obama's Race to the Top Program (RTTT) promoted STEM initiatives to reform education. Despite continued support into the present day, there remains a lack of research-based definitions or definitive frameworks to guide teachers (Johnson, 2019).

In the education field, including but not limited to STEM education, integration is seen as a deliberate attempt to connect content areas to make learning more engaging and relevant to real life. This is in contrast to traditional methods that partition disciplines into separate classes and activities for learning. Czerniak and Johnson (2014) argued that the practice is grounded in constructivist epistemology and a student-centered approach focused on providing developmentally appropriate and responsive contexts for learning. The movement towards common core standards in Math, Reading and Science supported integration by including affordances for cross-cutting interdisciplinary links. Integration has recently made considerable gains and support from STEM policy initiatives; concern for college and career readiness has also lent credibility to the practice. The practice of discipline integration has been a consideration for over 100 years, although the authors cite numerous obstacles to implementation such as a lack of interdisciplinary curriculum materials, the scheduling of instructional time in discipline-specific classes, and the absence of collaborative planning time. With the recent emphasis on accountability measures, teachers question whether integrated teaching can meet the demands of standardized testing, despite empirical evidence that suggests that integration is an effective and efficient way to cover the multitude of standards addressed by high stakes assessments.

A 2018 report from the Department of Education, *Charting a Course for Success: America's Strategy for STEM Education*, sets three broad goals for STEM education. The first is to build solid foundations for STEM literacy, and the second is to increase diversity, equity, and inclusion in STEM. The final goal is to prepare a STEM workforce for the future (Committee on STEM Integration, 2018). The report promotes transdisciplinary activities for learners that include innovation, entrepreneurship, and problem-based learning using authentic scenarios that integrate multiple disciplines, including rigorous use of math and science content. STEAM integration has gained interest as well, defined by Jolly (2014) to offer more diverse learning opportunities that apply art to real situations through the inclusion of design, creative planning, or performing arts. However, there remains a lack of integrated STEM or STEAM instruction in K-12 education.

Recent educational policy at the state and federal levels has narrowed the lens to focus on computer science as a priority in STEM education (Alivisatos, 2017), but other initiatives emphasize a broader range of skills that connect the classroom to the workplace. The Institute for the Future (Davies, Fidler, & Orbis, 2011) identified 10 skills that learners will need to develop for success in the workforce: sense making, novel and adaptive thinking, social intelligence, transdisciplinarity, new media literacy, computational thinking, cognitive load management, design mindset, cross cultural competency, and virtual collaboration. However, the commitment to 21st-century skill development continues to be constrained by a reliance on standardized and high stakes testing as an accountability metric (Nehring, Charner-Laird, & Szczesiul, 2019). STEAM pedagogy combines the integration of content standards and career readiness skills across the disciplines with opportunities to develop these advanced process skills.

In Pennsylvania, the PA SMART and Teachers in the Workforce programs are two capacity building grant programs designed to "accelerate learning and professional development in the fast-growing fields of STEM and computer science" (Pennsylvania Department of Education, 2018) and "support and enhance college and career preparations in classrooms across Pennsylvania" (Pennsylvania Department of Education, 2020). In January 2020, RSD was awarded a \$25,000 Teachers in the Workplace (TIW) Grant from the Pennsylvania Department of Education (PDE). This work-based learning experience featured two phases: professional

development opportunities for teachers and workplace exposure for both teachers and students. Teachers interacted with workplace professionals at three sites, both in person and virtually. The professional learning emphasized integrating STEAM pedagogy and career standards into lesson plans that offer opportunities to support the development of process skills that prepare learners for the 21st-century workplace.

1.1 The System

The statement of mission and values for my small school District (RSD) declares:

Recognizing the importance of providing our students with lifelong learning skills, the RSD's vision is to prepare each student for a successful collegiate education and/or employment within the global workforce. We pledge to do this through a commitment to competitive academic programming, personalized attention, and by providing our students with a variety of learning opportunities that assist each of them with discovering their talents and potential. By committing ourselves to this vision, we strive to be one of the most academically competitive school districts in the region.

The purpose of this mission statement is to drive decisions regarding coursework and services. What does it mean to prepare students for a successful college education or employment in the global workforce? There will be more than 1.3 million job offerings in computer and mathematical occupations available in 2022. In addition, advances in technology will require some computer literacy in most jobs, including those in industry, manufacturing, and service areas that do not require a four-year degree (Google, 2015). Like many school systems in the area, the district has been working to develop mechanisms for improving STEM and STEAM opportunities.

Appendix A contains a document analysis of district literature found on the website that mention both STEM and STEAM initiatives. Many show support for STEM and STEAM activities designed to prepare students to participate fully and meaningfully in the evolving workforce.

It is notable that the terms STEM and STEAM are used interchangeably in district literature. District administrators and professional staff appear to be unclear about the difference between STEM integration and STEAM integration. Although STEM knowledge is required to solve problems and foster innovation, the focus on creative thinking that STEAM integration promotes is often more engaging and can enhance disciplinary learning in STEM content areas (Henriksen, 2014). Similar districts in the area have a dedicated STEAM teacher at the elementary level who provides direct instruction to students that may include engineering design process activities, project-based learning, problem-based learning, maker activities, coding, and computer science skills. Herro and Quigley (2020) recognize that, while valuable, these strategies may not be the most effective to enact STEAM instruction and recommend a framework to guide curriculum design and expand opportunities for integration into classroom instruction.

Currently, the district does not have a comprehensive K-12 Computer Science or STEAM curriculum; its formal curriculum for STEAM integration begins in seventh grade. In a national study, principals and superintendents report that the lack of a dedicated computer science teacher or STEAM teacher is due to budgetary restraints, not due to a lack of commitment to STEAM and computer science as a relevant and necessary addition to the K-12 curriculum (Google, 2015). This situation is exascerbated in my small district, where funding issues have reduced the number of teachers and administrative staff. This situation will likely intensify as the district struggles to meet health and safety standards, and adjust to lost revenue as a result of the COVID-19 pandemic. In a 2019 interview, the RSD Superintendent stated that she felt that a full-time STEAM coach

position would be ideal but that it did not seem feasible due to funding and competing priorities, such as maintaining smaller class sizes and boosting growth measures assessed and reported through high stakes testing. During the 2020-2021 school year, the current superintendent, administrators, and school board members focused on safety measures and staff adjustments such as additional building substitutes and custodians.

Beaver and Weinbaum (2012) offer a framework to evaluate a school context and its ability to implement change. This school district, one of the smaller districts in the state, can be understood through this framework, which identifies four areas that impact an organization's change capacity: resources (e.g., facilities and materials), human capital (e.g., personnel to develop and teach curricula (e.g., shared stakeholder commitment), social capital (e.g., shared stakeholder commitment), and program coherence (e.g., fidelity across the system). One challenge in the district has been a lack of technology resources, such as iPads, laptops, and tools to teach physical computing and integrate technology. Many districts have implemented one-to-one device programs as early as kindergarten, when each student is given a device for use during the school day or beyond. RSD previously issued devices to students beginning in ninth grade. During the remote learning period brought on by COVID-19 restrictions, the district began to provide student devices across all grade levels. Expansion of technological resources during COVID makes it more feasible to introduce STEAM teaching pedagogy.

There is an additional absence of human capital, meaning teachers with a deep understanding of STEAM education or a clear conception of the 21st-century skills appropriate for a changing world. District professional development has not included the necessary pedagogy or content understanding to assimilate technology into instruction in a manner that builds students' technological literacy, a problem that is consistent in elementary education settings (Barendsen et al., 2016). Social capital, in this context, a shared commitment to STEAM integration, has decreased over the past few years, possibly due to the loss of an administrative position devoted to advancing curriculum, delivering professional development, and monitoring student achievement. In 2019, a restructuring of the RSD system spread administrative duties around without replacing a retiring administrator. As a result, administrators in each building share responsibility for curriculum supervision and development. In addition, competing commitments from existing mandates such as the Every Student Succeeds Act (ESSA) have directed program coherence efforts. With COVID-19, administrators, parents, and teachers directed their attention towards safety measures and other organizational issues, although remote learning did intensify the need for students and teachers to become more adept at using technology. Teachers, in particular, were tasked with learning to use online and then hybrid delivery modes for the 2020-2021 school year, as well as adapting classroom instruction to maintain social distancing and health protocols.

1.2 Stakeholders

RSD is a small school district serving two adjacent towns located in the suburbs of a medium-sized city at the northern edge of the Midwest. A part of the Rust Belt, the area has seen economic decline and remains focused on rebuilding. The district serves approximately 960 K-12 students who are separated into three buildings based on age and location. Students from two primary schools merge at the Junior/Senior High School and begin formal STEAM instruction, including robotics, human-centered design, digital media modes and computer science coursework. Students at the junior high level often arrive with inconsistent experiences related to

STEAM fields. This has numerous root causes, from access to technology and enrichment experiences at home to access to technology at school. Teachers' assimilation of STEAM practices varies widely between elementary school buildings, grade levels, and even between teachers in the same building and grade level. Although the Junior-Senior High School has a formal STEAM program in seventh and eighth grade, teachers in grades 9-12 often resort to traditional teaching methods.

Research reveals differences in the ways that teachers, parents, and students utilize technology related to socioeconomic levels and other factors (Dolan, 2016,; Fluck et al., 2016). Although student access to devices and experiences using technology outside of school has increased, there is a difference between the ways students use technology at home and how they need to use it at school. Dolan (2016) pointed to disparities between home use and the ways that teachers introduce and support student technology use. One explanation for this may be that, although technology use in school has increased, training for teachers and technical support has declined (Francom, 2020). There is a call for educators to leverage how low-income and culturally diverse students use technology in order to provide more inclusive and responsive opportunities (Dolan, 2016). To do so, school districts should develop policies and curricula that integrate technology in ways that move students beyond the practice of consuming technology and foster their abilities to become active producers of technology instead.

The students at RSD represent a heterogeneous class system that ranges from approximately 39 percent who qualify as socioeconomically disadvantaged to many students from privileged upper-class backgrounds. There is a noticeable discrepancy between the socioeconomic statistics of the two elementary schools in the district, as illustrated in Table 1. Elementary V2 is a Title I school and qualifies for the Community Eligibility Plan, which means that breakfast and lunch are provided without charge to all students in the building. These students may arrive at school with limited access or experiences related to technology, a phenomenon sometimes referred to as the Digital Divide (Dolan, 21016).

The term Digital Divide reflects a binary view of either access or a lack of access to devices and the internet. However, the differences among technology use and users are much more complex and exacerbated by multiple factors such as poverty, teacher training levels, cultural misunderstandings, and implicit racial or gender bias (Dolan, 2016). To bridge these gaps, educators need professional development that targets instructional use of technology. These differences seem to spill into the workforce as well. The narrow and popularized depiction of STEM fields may discourage some minoritized students from pursuing STEM fields and being interested in STEM topics (Quigley & Herro, 2019). Jolly (2014) suggested that STEAM integration, which works to ground STEM knowledge into real world issues with room for creative application of arts-related skills, may eventually make STEM fields more attractive for underserved populations.

Table 1	. RSD	Demogra	phics
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School	Population	Socioeconomically Disadvantaged
Junior Senior High	430	34%
Elementary T1	346	21%
Elementary V2	181	70%

The district worked to build the STEAM and Computer Science (CS) program at the middle school level, as noted in interviews with the prior superintendent, CS teacher, and Junior/Senior High School principal. The CS teacher at the high school noted that she has seen a rise in enrollment in her two AP CS classes, especially among female students (personal communication, October 2019). An equity audit revealed that this increase does not apply to minoritized students, who are not well represented in those classes. There is general acknowledgment regarding the underrepresentation of minorities and women in STEM fields (Jones et al., 2018). A RAND publication (Google, 2015) reports that Black and Hispanic students are less likely to have access to computer science, which puts them at a disadvantage for post-secondary schooling and affects their opportunities to advance in the workforce.

Integrating radical changes in the classroom to meet the needs of society is an adaptive challenge, one that requires adjustment in the priorities, beliefs, habits, and loyalties of all stakeholders involved (Heifetz, Grashow, & Linsky, 2009). This challenge is visualized through a fishbone diagram (Figure 1). A fishbone diagram is a way to analyze factors that influence stakeholders, institutional processes, and resources within the context to identify deficits (Bryk et al., 2016). As a tool to assess cause-effect relationships, it can help to reveal different perspectives and shed light on the connections between elements in the system. Figure 1 illustrates the context of the local system by revealing the primary and secondary drivers that shape the problem space.

The drivers include resources, knowledge, and support for STEAM education that affect all stakeholders. Teachers and administrators struggle to prioritize STEAM education over content standards that are subject to accountability measures. The financial status of this small district limits the ability to support new initiatives with appropriate professional development (PD) and administrative support. Although district literature seems to prioritize the development of STEM and STEAM curriculum measures, expectations that support more traditional modes of teaching are ingrained in the system.

School administrators and practitioners are aware of the importance of incorporating STEAM activities, particularly skills related to technology use, as early in the curriculum as

possible. The prior district superintendent, Dr. P, stated that she would like to see a systemic K-12 curricular sequence that integrates STEAM education and CS skills (personal communication, July 2018). Dr. P discussed several stakeholders who need to be engaged, starting with the school board, who guide and approve the budget process, and parents, who she felt were in support of developing a more comprehensive STEAM program. She expressed that some teachers were intrinsically motivated to innovate their practice, but she felt that others need help.



Figure 1. Fishbone Analysis of Factors Influencing RSD STEAM Integration

Other district administrators are in support of the integration of STEAM and computer science activities as well. In the fall of 2019, the two elementary school principals worked with the superintendent to create a job description for an "Elementary STEM Coordinator" as a supplemental position for a teacher after a full-time elementary level STEAM position was cut. They both expressed that STEAM integration is important in interviews, although they did not want to overload teachers adjusting to organizational and curriculum changes. The school principal's support is a key factor in creating conditions that help teachers persist through

challenging conditions such as changes in practice or curriculum (Bryk et al., 2015). Two factors cited by the building principals that deprioritize the integration of technology and STEAM activities are concerns with high stakes test scores and a lack of knowledge about STEAM and Computer Science curriculum components. With the pandemic, new and more pressing competing commitments have taken shape.

School board and community members are in support of implementing STEAM education and career readiness. The District's strategic plan for 2019-2022, developed by a team of school board members, community members, local business owners, educators, and parents, contains references to future readiness. Language indicates a concern for preparing students for the global workforce and developing students with the capacity to become lifelong learners. Parents in the district established a foundation in 2015 to grant funds to district educators for implementing innovative, creative STEAM projects that support the development of 21st-century skills. This parent-run organization is supported by the community and has given over \$25,000 in grant awards. In an interview, one REF Board member stated that it would be beneficial for students to have STEAM experiences in elementary school, particularly those that exposed students to coding and supported the development of skills in math and science (personal communication, 13 October 2019). She felt that her thoughts were representative of most parents. Responses to an informal survey indicated that parents felt that it was important to integrate computer science and STEM/STEAM activities into the elementary level instruction, although the use of STEM and STEAM as synonymous indicates a lack of understanding differences between the two terms.

Bryk et al. (2015) recommended that school reform efforts focus on the group at ground level with the most knowledge and experience about what works and what does not work: the teachers. Although schools have a hierarchical structure with formal authority resting with the principal, what happens in the classroom is dependent mainly on the teacher. Seven out of 10 teachers surveyed in early 2019 responded that it was of utmost importance to integrate computer science and STEAM as a part of regular curriculum activities in elementary school. Some teachers expressed dissatisfaction with their familiarity with STEAM content, tools, and methods. Elementary teachers are tasked with teaching all core subject matters, limiting the depth of their knowledge in technical areas, especially those associated with STEAM topics (Peters-Burton & Botov, 2017). All the teachers I spoke with related the need for ongoing and adequate professional development to address this gap.

Six district teachers from grades 4, 5, and 6 attended professional development sessions provided by the PDE, established as a part of a 2019 PA SMART Grant. This training focused primarily on integrating computer science and coding activities. Interest in promoting computational thinking as a necessary component of K-6 education, rekindled by an article on the values of computational thinking in children (Wing, 2006), has gained national and international attention in the education community. The teachers involved in the grant have all integrated coding activities into their classroom practices. During an interview, a fourth grade teacher involved with the Targeted Grant said that she noticed a high degree of interest and engagement in both her male and female students while using Code.org. Curriculum. She felt that curriculum activities that integrated STEAM content areas were valuable (personal communication, 25 October 2019).

A second interview with a veteran third grade teacher who was not a part of the PA SMART grant implementation team revealed the same level of openness towards integrating STEAM activities into her classroom practice (personal communication, 22 January 2020). She indicated that she would need professional development to feel comfortable and confident integrating STEAM principles, especially coding activities. She felt it was important for student outcomes

and a better use of instructional time than teaching siloed content areas. Her attitudes are consistent with Margot and Ketler's (2019) review of literature regarding teachers' perceptions of STEM integration. They found that teachers valued STEM for its cross-curricular nature and inherent motivation of students but felt they needed support through professional development, organizational flexibility, and ongoing collaboration.

In summary, STEAM integration at RSD is affected both positively and negatively by factors within the system. Figure 2 illustrates the relationship between factors that influence or restrain the goal of STEAM education. For example, there appears to be administrative support, yet that support often shifts to other concerns, such as core curriculum commitments or decisions in response to the recent pandemic. The school board, which sets the budget, has prioritized STEAM integration in district literature but is tasked with keeping costs at a level that deters additional taxation. While some parents support STEAM, others may be confused by the term and gravitate towards more traditional instruction modes. Teacher enthusiasm is tempered by a lack of knowledge about STEAM pedagogy and systemic constraints.

Force Field Analysis

Problem There is a lack of

STEAM curriculum integrated into elementary level and 7-12 grade classes.



Figure 2. Force Field Analysis of Factors Supporting and Deterring STEAM Integration

1.3 Problem of Practice

The improvement of schools, and the teaching and learning that occurs within these institutions, is a shared concern. Federal, state, and local policy and documents support a shift in practice to implement STEM integration and 21st-century process skills into classroom practice (Committee on STEM Integration, 2018; STEM in PA, www.education.pa.gov; RSD State of the District 2019). President Obama's Race to the Top (RTTT) grant program acted as a catalyst to

move STEM into the spotlight (Johnson, 2019). STEAM education, a policy movement and broader education movement, emerged as early as 2009 (Allina, 2018). As a result, many educators have begun to recognize the added value of cultivating creative thinking by connecting the arts to STEM content, promoting STEAM to engage all students and prepare them for the future. However, RSD teachers do not consistently integrate STEAM lessons that develop 21st-century workforce skills (Davies, Fidler, & Gorbis, 2011) into their classroom practice.

This problem can be addressed by involving stakeholders within the system. Mintrop (2016) suggests a design development partnership to expand the intellectual lift and social capital of an organization, even though it requires more time and energy from the system. The author describes three different types of co-design partnerships (CDPs): Consultive CDP, Mediated CDP, and Integrated CDP. Each approach requires collaboration between researchers familiar with the professional knowledge base and practitioners in the field. Mediated CDP calls for scholarly practitioners who are trained in problem-solving, design development, leadership, and research methods to "form, nurture, and facilitate co-design teams in their local systems" (Mintrop, 2016, p. 95). As an EdD scholar, teacher, and community member, I am in a unique position to utilize my position as Elementary STEM coordinator and Professional Development Committee Chairperson to bring about small tests of change.

Mintrop (2016) points out that the singular scholarly practitioner is often a lone voice in the crowd. Under such conditions, a single individual can rarely sustain multiple iterations and change ideas. However, there was a positive response from all stakeholders to STEAM integration into RSD school programs, although limited understanding as to what effective STEAM instruction entails. This indicates the need for ongoing professional learning experiences and support for teachers, which necessitates a review of literature on professional development and STEAM related professional development to guide the TIW workshop and inform subsequent efforts to support STEAM integration.

2.0 Review of Supporting Knowledge

2.1 Introduction

In his sociological portrait of the teaching profession, Dan Lortie stated that the teacher workplace is not "organized to promote inquiry or to build the intellectual capital of the occupation" (2002, p. 56). Although his seminal book, *Schoolteacher*, was first published in 1975, some of the factors he cited as limiting the career development of teachers remain. The hierarchical organization of public-school systems continues to create conditions for teachers to be supervised, not nurtured. Standards, curriculum, and even curriculum resources imposed from individuals outside the teaching profession squelch the ability of teachers to develop materials and lessons based on their knowledge of the content they teach and their understanding of how students learn best. In addition, the powerful influence of what Lortie referred to as the *apprenticeship of observation* supports subconscious compliance to traditional teaching methods at both the individual and collective levels.

The emphasis and nature of in-service opportunities often support the socialization of teachers to follow established teaching methods and techniques. Professional learning activities are sometimes labeled "teacher training," which implies a behaviorist-based factory view of education (Easton, 2008). The proletarianization of teacher work is compounded by a political and ideological climate that supports reform efforts imposed by policy makers far removed from the classroom (Giroux, 2002). This removes the responsibility for selecting, planning, and designing curriculum from those tasked with implementing it. Despite feelings of pedagogical discontent (Southerland et al., 2011), teachers often feel powerless to affect changes in their practice. To

combat this situation, professional learning should include experiences that affect the skills, behavior, knowledge, attitudes, and aspirations of those involved (Easton, 2008).

Borko (2004) identified four elements that influence the impact of a professional development experience on teacher learning. First is the *PD program*, then the teacher *participants*, the *facilitator*, and the *context* of the PD. She classified professional learning programs into three phases that scaffold the findings in subsequent phases. Phase 1 Research Activities look for evidence that a professional learning experience can add understanding and transform practice in classrooms. Researchers focus on the individual teacher as the unit of analysis and the professional development program, although they recognize the interconnections that exist among all four elements. The author acknowledged that teacher learning can occur in many different contexts, such as informal exchanges between teacher-learners along with formal professional development workshops presented by facilitators from inside or outside the teaching context. Teacher artifacts, such as lesson plans, lesson videos, or student work samples, can provide records of practice that can serve as a vehicle for or give evidence of teacher learning.

Ball and Forzani (2009) argued that professional learning experiences should focus on finetuning the tasks and activities of teaching (practice) instead of emphasizing beliefs about and knowledge of teaching. These authors used the term "training" to refer to professional learning that exposes teachers to professionally justified and specialized applications of practice that can guide decision-making in the classroom. This shift from what teachers *know* to what successful teachers *do* to support student learning complements the movement from content-based traditional teaching to a more process-focused methodology. The authors recommended using exemplars, vignettes, and coaching to support teachers as they grow into professionals capable of responding to the complex demands of teaching. Desimone (2009) also called for professional developers and teacher educators to move beyond discrete activities such as workshops and conferences to consider a wider view of what counts as professional learning experiences. Book clubs, study groups, professional learning communities, curriculum design teams, school improvement committees, artifact analysis cohorts, video, and lesson analysis can all fall under the umbrella of professional learning. By conceptualizing the qualities of all types of effective professional development and removing bias in data collection, the educational community can build empirically based knowledge to improve teachers' learning opportunities.

Quality professional learning experiences for teachers can directly impact their willingness to innovate to improve the quality of learning for students (Hauge & Wan, 2019). Putnam and Borko (2000) ground considerations about professional learning in perspectives about the societal and contextual nature of knowledge acquisition. They recognized differences in professional learning as constrained by location and duration, indicating that different contexts are appropriate for different goals. For example, summer workshops seem to be more effective for introducing new subject matter and new thinking about student learning, while implementation goals are better served by synchronized activities that take place alongside actual teaching. The authors postulated that substantive changes in teaching will require "a combination of approaches situated in a variety of contexts" (p. 7).

One such substantive change is the move towards transdisciplinary teaching that characterizes STEM or STEAM teaching initiatives. STEM education, a term first coined by the National Science Foundation in 2001, has been an emphasis for federal and state policy for over 20 years (Bybee, 2013). STEAM education developed under the umbrella of a collaborative effort between the National Education Association, the National Science Foundation, and the National Endowment for the Arts (Allina, 2018). Despite the ambiguity in parameters between STEM and STEAM education (Jolly, 2014), it is clear that each requires novel approaches to teaching and learning.

At a recent press briefing (U.S. Department of Education, 22 January 2020), STEAM education was described as complementary to STEM and an approach to teaching through which students leverage the five content areas of science, technology, engineering, arts, and mathematics to build new understandings and solve problems that are authentic to the students' lives. Defining characteristics of STEAM education include creative outcomes with aesthetic or personal meaning; inquiry-based and student driven; a basis in experiential learning that focuses on processes and outcomes; and interdisciplinary teaching that incorporates standards in all subjects. Most of the policy directed towards developing STEAM initiatives is grounded in increasing the country's competitiveness in the job market and future access to economic well-being. However, some policy makers are concerned with equity issues related to gender, socioeconomic, and racial status (Allina, 2018).

Pragmatic and socio-historic learning theory is concerned with the affordances and constraints that enhance learning, which is situated in the context of intentions and a community of practice (Greeno, Collins, & Resnick, 1991). Bandura (1977) used the term self-efficacy to describe an individual's belief that they have adequate command over both the content to learn and the context for learning to implement change and teach others. Additional research suggests a relationship between teachers' feelings of self-efficacy and the successful implementation of innovative practice (Stein & Wang, 1988). Considering the impact of varied professional development interventions on teachers' feelings of competency in working with STEM and STEAM integrated curriculum for the first time is warranted. It is important to identify salient

features of training that increase feelings of psychological safety, which can enhance teachers' willingness and comfort as they try out new practices (Wanless, 2016).

Many factors challenge the implementation and integration of STEM or STEAM education. Teachers list concerns with time and pacing, student mastery of essential content, planning for discipline and standards alignment, issues with technology deficits, and concerns for assessment options (Herro, Quigley, & Cian, 2019). These include the traditional organization of the school day based on discipline segregation (Nadelson & Seifert, 2017). Idealized STEAM or STEM integration often involves additional resources such as technology, kits, construction or art supplies, and storage room for materials (Quigley & Herro, 2019; Stohlman et al., 2012). Successful STEAM integration hinges on the intersection of teachers' disciplinary content knowledge, pedagogic content knowledge (Shulman, 1987), willingness, and feelings of efficacy (Nadelson et al., 2013). Quigley and Herro (2019) list another factor that affects integration efforts: the level of coherence and collaboration or the existence of a shared vision among administration, community members, and colleagues. With that in mind, a study of professional development models for STEAM integration may provide helpful insights into design principles and measures of effectiveness to guide an intervention in a localized context.

For this review, I searched for articles using the keywords *STEM integration*, *STEAM integration*, and *professional development*. I looked for peer-reviewed articles but also searched dissertation studies because the appendices often offer complete study documents such as questionnaires, surveys, and interview protocols. I avoided studies involving pre-service teachers as this intervention will be directed towards in-service educators. I began by considering writings about professional development in general, then focused on studies of efforts to support teachers' abilities to integrate STEM and STEAM education to inform the plan for a TIW Professional

Development module. I then discuss some literature with details about research measures and tools used to evaluate the effectiveness of STEAM PD modules. Due to constraints imposed by the pandemic, I also looked for literature about online or virtual experiences for teachers.

2.2 Professional Development Models in STEM and STEAM

Effective professional development should be organized around a core conceptual framework to include content focus, active learning, coherence, duration, and collective participation (Desimone, 2009). One study recognized the role content knowledge, pedagogical content knowledge, and resources play in successful STEM teaching. Researchers and teachers in a public middle school worked with a sustained curriculum program called Project Lead the Way (PLTW) to integrate STEM teaching (Stohlman, Moore, & Roehrig, 2012). PLTW is a non-profit organization that has developed a curriculum to support middle and high school-aged students to gain STEM related skills and content. The PD effort, which included a two-week mandated PLTW summer training and access to PLTW Trainer support during school year implementation, emphasized supporting the teachers' content knowledge, planning, and organizing. The teachers also attended an ongoing STEM integration Academy (five days of training and 16 hours of Professional Learning Communities, or PLCs). In addition, a 3M grant funded graduate student fellows from a local university who provided classroom assistance, supplementary materials, and ideas for curriculum implementation. Data was collected using three formal observations with a structured protocol, weekly observational field notes, and weekly conversations from informal interviews. Researchers used the results of their study to develop the s.t.e.m. model as a framework for professional development that promotes teaching integrated STEM education. They found that

the support of those outside the context, university, and PLTW personnel had positive effects, as did collaboration time with colleagues. However, program continuity suffered from instability prompted by teacher turnover and concluded that STEM integration requires dedicated, organized, and knowledgeable teaching professionals.

Du et al. (2019) reported on a three-year state level Math and Science Partnership grant program (MSP) designed to improve the quality of STEM instruction by strengthening teacher knowledge of STEM content and pedagogical content knowledge. Fifty teachers attended 135 hours of professional learning in three consecutive summer academies and release day workshops totaling an additional 60 hours of embedded PD. The professional development was implemented in four phases introducing STEM pedagogy, a summer internship experience, and modeling instructional strategies. Teachers collaborated in grade-level teams to develop problem- or projectbased learning units that incorporated math, scientific inquiry, engineering, and technological design. Data measures consisted of interviews and multiple classroom videos of lessons. Over three years, teachers showed improvement in lesson design, implementation, and classroom culture and increased the rigor of math or science content. Exposure to an outside PD source decreased the need for support within the teachers' organization, although desire for additional resource materials and technical training increased. As teachers' feelings of efficacy and experiences with STEM integration increased, their curiosity and desire for continued growth did as well.

The *i-STEM* summer project sought to develop the content knowledge, use of inquiry-based strategies, and efficacy of the 230 teachers in grades 4-9 who attended a four-day residential professional development experience (Nadelson et al., 2012). The project included 32 hours of instruction, four hours of planning, and six hours of networking and socialization opportunities.
Lectures, panels, and presentations developed teachers' knowledge of STEM content in 14 strands such as energy, space, the human body, placer mining, materials science, and mathematical thinking. The teachers received a classroom kit for each strand they attended, including a syllabus, teaching materials, and a pre/posttest based on content knowledge covered in the strand. The teachers participated in active learning through lab activities, field trips, and presentations to develop content and pedagogical content knowledge. The PD model was based on models of adult learning that theorized connections between efficacy for instruction, pedagogical discontentment, and implementation of inquiry instruction. Similar to Du et al. (2019), the study found that increased levels of teacher comfort and feelings of efficacy teaching STEM had a positive effect on levels of inquiry implementation. Researchers also found that increased efficacy decreased levels of pedagogical discontentment with STEM related practices and teaching methods.

Herro and Quigley (2017) reported on a PD collaboration in a large southern school district that was geared towards presenting new practice and resources while forming a community of practice to support these innovations. Summer workshops on project-based learning, digital media, and learning and reflective practice provided 50 hours of content with support during the school year that included observations and planning meetings. The teachers explored an authentic STEAM scenario in groups using technology introduced through mini lessons. The teachers learned about and used Google classroom apps, digital storytelling and podcasting apps, and the Diigo online research tool while actively participating in a transdisciplinary problem-solving activity. The researchers reported that having the teachers take on student roles and utilize technology both in the role of a student and as teachers had positive effects, as did affordances for in-person and virtual collaboration with other teachers and community partners. The research team found that teachers' perceptions showed positive changes in understanding the use of STEAM to teach content and technology use to enhance student learning. However, findings indicated that teacher understanding of transdisciplinarity was at the beginning stages, although they did see collaboration as an effective means to integrate multiple content areas and inquiry modes. An implication for other PD developers is that adopting and understanding transdisciplinary teaching, especially arts and humanities integration, may require repeated professional learning experiences and ongoing support for teachers in the field.

Darling-Hammond, Hyler, and Gardner (2017) examined 35 peer-reviewed or federally funded studies to identify commonalities of effective PD initiatives. Careful qualitative analysis revealed seven characteristics (p. 4). The first is that PD should focus on instructional content. The second is that teachers should have the opportunity to engage in active learning experiences consistent with adult learning theory. PD should offer affordances for collaboration with teaching peers and administrators, ideally in job-embedded contexts. PD should model effective practice, offer opportunities for coaching from experts, and be combined with mechanisms to support feedback and reflection. One final component is time; the authors found that PD sustained over weeks, months, or even years was much more effective than the"one and done" workshop method employed consistently in many school districts. The studies described above conform to the elements of best practice for professional development and included triads of committed university level researchers, administrators, and teachers.

The TIW project is limited to a three-day virtual workshop sustained and presented by teachers with limited support from university level experts. However, even relatively short PD interventions have resulted in positive effects on teacher confidence and efficacy integrating STEM teaching practices (Nadelson et al., 2013). The researchers evaluated the effectiveness of a three-day PD workshop that focused on content related to inquiry-based instruction, STEM

curriculum development, assessment, standards alignment, and management tips. Results indicated that even shorter PD interventions can yield a positive correlation between confidence for, comfort with, and efficacy towards integrating STEM teaching practices and content. They used demographic data that included years of teaching and levels of education but did not find those to be predictors of efficacy, leading them to conclude that teachers in all stages of their career would benefit from PD related to STEM integration.

A study by Jamil, Linder, and Stegelin (2018) found evidence that younger teachers were less likely to express support for STEAM teaching, which the researchers postulated could result from the emphasis on testing and accountability over the last 20 years. Participants attended a one day-five-hour conference that included a keynote session followed by two-hour workshops on math, science, technology, or art integration topics. A post-survey focused on measuring teachers' beliefs about STEAM education. The researchers found that some participants expressed only surface level understanding of STEAM integration and were more concerned with products or students' engagement over content and process development.

Kim and Keyhani (2019) studied the lesson plans and journal entries of one novice STEM teacher to monitor the development of that teacher on a framework rooted in stages of selfauthorship and internal foundations (Baxter Mangold, 2004, as cited in Kim & Keyhani, 2019). This study indicated that identity development is a vital construct to attend to during STEM professional development. In addition, findings supported involving teachers in curriculum design as a part of a professional development experience to increase their confidence and ability to reflect on their own teaching. The focus of this intervention is or teachers to author a lesson or unit plan that meets the goals of STEAM integration and career preparation standards.

2.3 Effective Online Professional Development

Recently, there has been renewed interest in the effectiveness of online professional development as it has become the preferred delivery modality during this pandemic. Prior to 2020, Online Teacher Professional Development (OTPD) was recognized as presenting advantages in both accessibility and potential for differentiation based on interest, content, and experience. OTPD has the added benefit of connecting teachers and offering affordances to collaborate outside of the local setting. Fishman et al. (2013), in a randomized experimental study with 49 teachers across the United States, compared face-to-face and online PD outcomes related to training to adopt a new environmental science curriculum. The study focused not only on teacher knowledge and beliefs but also on classroom instruction practice and student outcomes. The researchers found that gains in content knowledge, feelings of efficacy, and beliefs about teaching environmental science were comparable between the online and face-to-face modalities. Comparisons of classroom practice and student outcomes were comparable as well. However, slight differences among the number of contact hours between groups led the researchers to conclude that online PD had advantages, such as engaging in the PD as needed when implementing the new curriculum, which enabled participants to work more efficiently through the material.

In a response article, Moon et al. (2014) argued for more work on design issues for online PD. They listed variances such as asynchronous versus synchronous scheduling, expert or peerdriven facilitation, options to use video analysis, and ways that teachers respond through online modalities, and speculated on how these might affect outcomes such as teacher learning, teacher beliefs, classroom practice, and student gains. They called for researchers to make connections between theory and design by building an empirical base that supports their conjectures. Although online models for professional development have become more prevalent recently, there is a paucity of research regarding virtual professional development for STEAM integration. Pelton (2018) studied the responses of 405 teachers involved in online STEM-related e- learning courses in Alabama. Analysis of quantitative and qualitative data from multiple choice and open-ended survey questions and responses to prompts posted on social media sites indicated that online PD was effective at enhancing content knowledge, knowledge of STEM pedagogy, digital literacy skills, and feelings of self-efficacy. It is important to make affordances for collaboration and to create connections with classroom practices. Online professional development is an effective way to develop communities of practice, but it may take time for teachers to move from utilizing online resources to feeling confident enough to create and share online resources (Anastasiadis & Sotirious, 2017).

Despite the limitations in time and expertise available to conduct the TIW PD, this study highlights some guiding principles for the intervention. Nadelson et al. (2013) concluded that professional experiences to enhance STEM integration should have affordances for specific structures, exploration of materials, and concepts and collaborative conversations. First, enough introduction to a STEAM conceptual model (Quigley, Herro, & Jamil, 2017) must be included for teachers to develop effective unit plans. Teachers should be encouraged to build units based on familiar content to reduce pedagogical discontentment. It would be valuable to embed an authentic problem scenario into the course of the PD as a model, along with mini-lessons on relevant technology. Participants should have opportunities to explore career standards and resources that will support both content and process skills. There should be occasions for collaboration, both during the three-day workshop and as ongoing mechanisms for support during implementation in the 2020-2021 school year, if possible.

3.0 Methodology

3.1 Theory of Improvement

An intervention to bring STEAM integration into RSD will need to modify teachers' tasks and the processes and tools they use to expand and implement lessons. However, the complexity and multiplicity of learning ecologies make pure applied research on students, teachers, resources, and systems difficult. (Schoenfeld, 2006). Empirically based experiments attempt to fine tune "what works" through the manipulation of variables in a tightly controlled setting. However, researchers today seek to develop an understanding of the synchronous nature of "what works" with whom, when, and under what conditions, along with why and how those conditions are created. As an answer to this quandary, two schools of research that seek to improve teaching and learning have developed: Improvement Science and Design Experiments. Researchers and practitioners alike need to consider the suitability of these approaches to their area of concern (Lewis, 2015).

Design experiments are used to develop, test, and revise theories of learning and instruction. They are often pragmatic and focused attempts to engineer particular forms of learning and systematically study those forms of learning within a learning environment. Design experiments are "humble" (Cobb, et al., 2003, p. 9) in that they are often discipline based and focus on a narrow set of interventions, which become the basis to measure and analyze learning outcomes. These experiments may result in iterative descriptions of fine distinctions between learning outcomes and the optimal conditions conducive to those outcomes. Although often limited in scope, they can take many forms, such as one teacher and students in a classroom,

classroom collaborations between researcher(s) and teacher, interventions with pre-service or inservice teaching groups, or restructuring experiments to support organizational change in schools or school systems. (Cobb et al., 2003; Schoenfeld, 2006).

Improvement Science, on the other hand, is designed to instigate rapid small tests of change with the goal of more widespread organizational change. Although sharing in the iterative nature of design experiments, improvement science is committed to the continued fine-tuning of the tools, processes, and relationships in educational contexts instead of developing and testing theory. Proponents of Improvement Science first diagnose a problem by looking for variations in performance and root causes (Bryk, et al., 2016). Three questions guide improvement science: "1. What needs to be accomplished? 2. What change should be introduced and why? 3. What results will show that the change is actually an improvement?" (p. 114). Bryk at al. (2016, p. 9) recognize improvement science as a means of bringing change into organizations despite restrictions on capacity for change. The authors recommend looking at the specific tasks of the people in the system, the processes and tools they use, and how they are affected by policies, organizational structures, and norms.

The goal of improvement science research is understanding aspects of local context to integrate this insight into iterative solutions (Bryk et al., 2016, p. 80). An analysis of causal factors reveals many interrelated components regarding STEAM integration in my district. Most district curriculum resources do not include lessons that develop process skills. District professional development has not addressed the integration of STEAM elements and skills. Teachers carry norms that may have developed through the apprenticeship of observation, a phrase coined by Lortie (1975) to mean that teachers carry perceptions of idealized teacher behaviors and practice based on their experiences as students, which may not reflect current understanding of best practice

(Grossman, Hammerness, & McDonald, 2009). Teachers are not familiar with process skills required for success in the future workforce. In addition, teachers prioritize content and skills necessary for students to succeed on high-stakes accountability measures. Therefore, professional development must address some of these deficits.

Aim: Twenty percent of I School District classroom or content area teachers will improve STEAM integration and workforce preparation by developing and implementing at least one STEAM/career integrated lesson-unit plan during the 2020-2021 school year after experiencing a targeted professional development intervention.

3.2 Drivers and Driver Diagram

Bryk et al. (2016) recommend that improvement science practitioners identify a small set of key drivers, or hypotheses, to facilitate the desired change. By considering stakeholder perspectives and root causes, aims and drivers can be developed to formulate small change ideas leading to systemic changes. A *driver diagram* (Figure 3) is a visual tool that organizes knowledge, experience, and research to formulate change ideas based on change theory (Bennett & Provost, 2015). Mintrop (2016) recommended that intellectual leadership consult scholarly literature to make sense of the symptoms and patterns that lead to these inferences.

Mintrop (2016) defined *root causes* as factors that explain either a pattern or a deficit in a system. He distinguished those factors as *macro*, or attributable to the interplay between the many public, policy, and cultural influences that shape the system; *meso* as factors at the organizational level of the institution; and *micro* as factors influenced by individuals. These are not mutually exclusive; meso factors and macro factors, for example, often influence individual behavior at the

micro level. Many improvement scientists focus their efforts at the micro level and are thus concerned with pursuing quality in standard work processes, particularly individual work processes (Bryk et al, 2016). By choosing high-leverage processes to support, improvement scientists are more likely to achieve sustained and reliable outcomes, although Bryk stated that this is most effective when the community involved creates, tests, and refines these work processes. In the public-school systems, this would mean the intervention should target the classroom teachers.





Figure 3 shows the relationship among the aim, drivers, and change ideas. Perry, Zambo, and Crow (2020) argued that lagging outcomes represent a more extensive system-wide goal that may take more than one PDSA cycle to achieve. Leading outcomes are smaller but lead to the development of larger goals, known as driver measures. Leading outcomes are derivatives of the

drivers and may describe a process, tool, or norm that can become part of the change idea. A professional development experience should address the driver measures and develop those identified during a PDSA cycle. Process measures are more focused and determine more immediate effects of the change idea, in this case, the lesson plan artifacts developed by teachers. Finally, the improvement theorist should consider balance measures, which are not always immediately visible as these refer to the need to monitor the effects of the change idea on the system as a whole. In this study, it is essential to consider whether or not the change idea costs the system in terms of standards implementation, teacher evaluations, instructional time, or performance on accountability measures such as APA exams or state-mandated tests like the PSSA or Keystone exams.

Standard work processes in the teaching field have been subjected to different norms and theories of learning throughout history (Forzani, 2014). Frequently, educational practice is driven by behavioral and cognitive learning theories that rely on teaching strategies designed to facilitate the learning of discrete content or skills and the use of assessment measures to evaluate learning (Forman & Ford, 2006). Sociocultural learning theories, however, require a "practice turn" to interdisciplinary learning. In addition, there is a call to align teaching contexts, tools, and processes with those utilized in 21st-century workplaces.

A vision for STEM education articulated by the U. S. Department of Education suggested that there should be better connections between teachers, students, and the workplace (Tannenbaum, 2016). Educational policy makers have begun to recognize STEAM over STEM as a model that develops students' capacity for creativity, innovation, and problem solving to bridge the gap between acquiring disciplinary skills and workplace applications. This broader education model increases student engagement and builds the skills necessary to maintain the country's economic standing and global competitiveness (Allina, 2018). STEAM advocates have banded together to identify a set of "best practices" for STEAM initiatives. These include thorough planning that balances interdisciplinary standards within the context of authentic experiences that highlight career connections and real-world applications.

Developing new core practices, as defined by Forzani (2014), requires sophisticated levels of academic, relational, and organizational skills to manage classroom activities to include more collaboration, problem solving, personalized learning, student driven activities, and technology integration (Scott, 2015). Bybee (2013) defined STEM literacy for students as "the ability to learn to apply basic content and practices of the STEM disciplines to situations they encounter in life" (p. 5). By incorporating creative planning, communication skills, and/or performing arts into the mix, STEM evolves into STEAM ((Jolly, 2014). Teachers will need to incorporate even more components into a cohesive learning experience, which requires a distinct practice turn for teachers at both the *meso* and *micro* levels.

Professional development should support teachers' abilities to strengthen their students' growth in 21st-century competencies in conjunction with mastering disciplinary content (Hilton, 2015). Teachers will need to develop a knowledge base regarding 21st-century skills such as computational thinking, design mindset, and cross-cultural competency (Davies, Fidler, & Gorbis, 2011). This can be a challenge for teachers who have been educated in a traditional pre-service course of studies and who have little current experience outside of the classroom. For teachers to effectively train the future workforce, they need to know how the current workforce operates and understand the sub-skills that support the four main principles of creativity, collaboration, communication, and critical thinking (Bowen & Shume, 2018).

In addition, teachers will need to become familiar with a STEAM conceptual model for teaching. Shulman (1987) recognized that teacher knowledge takes different forms and situated content knowledge within broader considerations of knowledge of learners, contexts, systems, philosophy, values, and pedagogy (Ball, Thames, & Phelps, 2008). Understanding and organizing ideas in the context of a conceptual framework will facilitate the development of teachers' adaptive expertise (Grossman. Hammerness, &. MacDonald, 2009). Teachers may value STEAM implementation, but they often lack an understanding of transdisciplinarity and how adding the A for Arts integration can be accomplished (Herro & Quigley, 2017; Quigley, Herro, & Jamil, 2016). Grossman, Hammerness, and McDonald (2009) point out that while conceptual tools facilitate teachers' understanding of practice, they also need specific skill sets, referred to as core practices, to navigate classroom implementation. Professional development should balance theory with practical considerations for classroom practice.

Quigley and Herro (2019) grounded their STEAM conceptual framework in connected learning theory and recommended beginning with problem-based scenarios that connect to local issues and student interests. They identify two domains: the instructional content and learning context. They describe various dimensions to capture the ways that teachers can control, structure, and organize classroom elements to maximize a concern for both domains. Their approach specifies an instructional approach that enables teachers to provide opportunities for students to gain process skills while allowing for creativity and honoring students' differences.

A *problem-based delivery* means that teachers begin by creating a scenario that presents students with a challenge that is open ended but "relevant to the students' lives community, context, or culture" (Quigley, Herro, & Jamil, p. 5). This approach requires teachers to plan carefully to ensure that the problem addresses content and standards appropriate to the teaching

circumstances. Teachers should plan for *discipline integration*, which the authors idealize as transdisciplinary or interdisciplinary over simply taking a multidisciplinary approach. Teachers in this scenario should work to integrate the context of the scenario in relevant content from multiple disciplines.

Distinct from a problem-based scenario is the development of *problem-solving skills*, which the authors refer to as the cognitive, interactional, or creative skills teachers strive to develop in their students. The authors anchor these skills in the broader category of "21st-century skills". *Technology integration* is an important consideration to encourage and enable these skills. In STEAM pedagogy, teachers should go beyond the use of technology to provide learning materials and aspire to move students from the practice of consuming technology to using technological skills to build, improve, or share their solutions (Quigley et al., 2020).

This STEAM framework refers to the importance of building *authentic tasks* into the classroom experience. These tasks create connections between STEM careers and skills as applied to realistic tasks related to the problem scenario. Another feature of the STEAM framework is *student choice*, meaning that students have some autonomy over the process that will support their learning and products that develop as they work through the problem-scenario. The authors call for *assessment* tools that are embedded throughout the process to allow teachers to give frequent, formative, and high-quality feedback to students aligned to the problem area. By applying this framework, the authors feel that *equitable participation* will be enhanced by respecting students' diversity and responding to students' interests.

Teachers will need to develop the capacity to design an integrated and comprehensive unit plan. Independently authored lesson plans are artifacts that represent teachers' curricular and instructional priorities (Sias et al., 2017). Although problem-based learning has been identified as an effective vehicle to guide STEAM integration, many teachers lack experience, confidence, and proficiency needed to design of PBL units and develop cohesive curriculum units (Huizinga et al., 2014; Quigley et al., 2020). Giroux (2002) placed the blame for this on a technocratic approach to education that has attempted to routinize and standardize curriculum and instruction by removing it from teachers' control. A STEAM conceptual framework offers affordances for teachers to recognize the different histories, cultural practices, experiences, and talents of students in planning well-designed units. The STEAM conceptual model developed by Quigley and Herro (2019) embeds problem-solving skills, discipline integration, and classroom environment into considerations for how teachers create the learning context that facilitates STEAM learning and components for equitable participation and authentic assessment.

The TIW professional learning experience attempted to address these primary drivers by identifying secondary drivers. Bryk et al. (2016) described secondary drivers as levers to develop change ideas to be tested, evaluated, and, later, refined. In this case, participants encountered sources to help them understand essential STEAM practices and identify them in sample lessons. Participants learned about and defined critical skills needed to succeed in the future workforce through readings and other media. Teachers utilized sample lesson plans to identify both Pennsylvania Career Readiness standards and 21st-century process skills addressed in the lessons. Ultimately, teacher participants acted as curriculum developers and utilized a lesson planning template designed to facilitate the inclusion of STEAM teaching practices, foster the integration of 21st-century process skills, and address Pennsylvania state standards.

3.3 Change Idea and Intervention Overview

In January, RSD was awarded a Teachers in the Workforce (TIW) Grant. The grant application combined workforce site visits for teachers and students, and lesson plan development. The monetary award of \$25,000 made it possible to pay teachers the hourly rate as specified by the Contracted Bargaining Agreement in effect until 2023. Fifteen thousand dollars was allocated for workforce visits and \$10,000 for a professional learning experience to support lesson development. Our funding projection allowed 25 teachers to participate, but only 19 teachers applied to participate and write lesson plans. Due to COVID-19 restrictions, the grant funding was extended into 2021. This means that a second PDSA cycle may be possible with other teachers in summer 2021.

The quality of STEAM instruction is linked to the quality of professional development experiences made available to K-12 teachers, especially those willing to innovate their practice to include content and instructional practices that bridge the disciplines of science, technology, engineering, math, and the arts (Nadelson et al., 2012). Brown (1997) identified four key aspects common to foster communities of learning: agency, reflection, collaboration, and culture. I made every effort to build these four aspects into the experience, which was a challenge in a virtual setting. At a grant meeting in March 2020, a district administrator agreed to designate Professional Learning Community time during the 2020-2021 school year for sustained PD sessions concerning lesson implementation. Unfortunately, training for virtual teaching at the start of the 2020-2021 school year took the place of contracted PLC time. Although this PD initiative was limited to three half-days with no scheduled follow-up embedded throughout the school year, I designed the PD experience to align with research on effective STEAM professional development practice and design.

Due to COVID-19 restrictions, teachers participated virtually. Table 2 gives a brief overview of the format. Participating teachers learned about forces shaping and changing the workforce through text and other media, then had opportunities to reflect on their own classroom practice (Davies, Fidler, & Gorbis, 2011). RSD teachers learned about the components of STEAM integration based on a STEAM Conceptual Framework (Quigley, Herro, & Jamil, 2017). Teachers collaborated to write lesson plans that integrated Career Awareness and Preparation (13.1) standards, the Career Education and Work Standards and the STEAM Conceptual framework. Case studies are an effective way for teachers to analyze teaching in a collaborative, formative manner (McDonald, Kazzemic, & Schneider Kavanaugh, 2013; Putman & Borko, 2000; Shulman, 1986). Vignettes or videos of STEAM Integration lessons provided a basis for case study before teachers built their lessons. Appendix C contains complete agendas for each day.

	Day 1	Day 2	Day 3
Guiding Question	What is the purpose of education?	What are some core practices that support the development of key competencies for students today?	How can we plan classroom activities to promote 21 st century process skills and support STEAM integration?
Activities	Ice Breaker: Scavenger hunt Content Development 21st-century skills PA Career Readiness standards https://app.edu.buncee.c om/buncee/b460780a05 3a474c957f5ef200828d 2c	Ice Breaker: Build IT challenge Content Development Project Based Learning STEAM conceptual model Case/lesson study Lesson idea share https://app.edu.buncee.co m/buncee/16e11ced263e 4e37a341c3859eadc835	Ice Breaker: Disruptus cards Content Development Lesson plan development <u>https://app.edu.buncee.c</u> <u>om/buncee/41f1ddd773</u> 6246899306bb80a7ab5b be

Table 2. Overview	of Professional Develo	pment Intervention
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Attempts to assess the efficacy of a PD model with its affordances for collaboration in a professional community of learners instead of the traditional content-based workshop is valuable in understanding how PD formats influence and support the implementation of innovative practice. Online PD is effective at supporting teacher learning. Therefore, this study aimed to gather data on one online professional development model in order to assess the efficacy of its format to support participants beyond the scope of the workshop and to optimize such training efforts in the future.

The TIW grant application addressed Career Awareness and Preparation (13.1) standards of the Career Education and Work Standards. A team wrote the grant plan: two high school special education teachers, two elementary school guidance counselors, and this researcher, a first-grade teacher who also serves as the Elementary STEM Coordinator. Work-based learning experience included teacher site visits or virtual exposure to professionals in three STEM-related workplaces: the Pittsburgh Zoo, the WISER facility of the University of Pittsburgh Medical Center (UPMC), and the Carnegie Museum of Natural History. Participants learned about how these professionals use technology, their career paths, and educational experiences. In particular, the presenters also addressed that process skills are applied in their professional lives.

The grant was intended to emphasize the need to develop both students' content knowledge and process skills by exposing teachers to different careers through visits to STEM-based facilities. The immediate goal was for teachers to create STEAM lesson plans that enhance student learning and attend to career related process skills such as collaboration, creativity, problem solving, communication, and critical thinking. The eventual goal, or lagging outcome, was for students in each grade level to experience STEM field career prospects through STEAM-integrated classroom lessons that could include guest speakers, virtual interaction, or site visits. Approximately 20 teachers participated in the site visits and committed to attending a professional development experience to develop a lesson plan for use in the classroom. Through the grant award, the district was able to compensate teachers for their participation in site visits and lesson planning. The grant team determined that only staff members who had attended one or more of the June workforce visits could be included in the August PD and lesson planning. During an application survey, 33 out of 86 teachers expressed interest in lesson planning, although only 19 attended the virtual PD. Teachers worked in teams or individually, and 10 lesson plans were submitted to the grant review team. I present analysis data from nine of those lesson plans, as one was too incomplete to consider.

Perry, Zambo, and Crow (2020) pointed out the dilemma the scholar practitioner faces when conducting tests of change in their own organizations. As an insider collaborating with other insiders in the organization, it was essential to remain impartial and unbiased while acknowledging that the desire to see evidence of improvement could skew interpretation and affect the ability to be objective. By using the term insider, I emphasize that this intervention is directed at my colleagues and fellow teachers. I have been teaching in the district for over 20 years and have worked in both elementary schools and parented three students who matriculated through district schools. I developed and facilitated the professional development and participated in the site visits. I provided my own sample lesson plan for lesson study by the group and worked on a new lesson while presenting.

It is important to acknowledge the researcher's personal privilege by virtue of race, gender, sexuality, socioeconomic status, and education level. As a participant in the professional development and lesson planning, I acknowledge my position as a white heterosexual woman with a higher degree of socioeconomic stability and education than many of my colleagues. Although I

have no formal authority in the district that puts me in a position of power over other participants, these aspects of my identity may have influenced both my thinking and the responses or reporting of other participants. My insider status and identities could result in subjectivity in my interpretations of data and may possibly have affected other participants' responses. When possible, I engaged in strategies to mitigate skewed interpretation, including piloting measures with colleagues outside of my district and having colleagues help analyze my results. Another precautionary step was to ask for participant check-ins during the professional learning experience and during lesson planning.

3.4 Research Questions

What do in-service teachers in my district report as their STEAM teaching efficacy before and after a professional development intervention on STEAM integration?

In what ways do in-service teachers in my district integrate process skills, career standards, and a conceptual model of STEAM teaching practices as defined by Quigley, Herro, and Jamil (2017) into their lesson planning?

What do in-service teachers in my district identify as additional supports that will assist them in implementing these lesson plans?

3.5 Plan-Do-Study-Act Cycle

Bryk et al. (2016) called for change agents to begin by evaluating the capacity for change in an institution. They reminded readers that widescale reform is rarely successful unless the workforce is prepared and capacity for the change cultivated. First, individuals must have the know-how, defined as the specific practical knowledge needed for a change to happen. A second factor includes both organizational and human capacity. In this case, capacity means enough teachers within the organization have the ability to set the change idea in motion, and organizational supports validate the expansion of the idea. "The rate of spread of an effective change is a function of the size of the current expertise base that can teach and mentor others how to do this work" (p. 119). Last, the authors recommended that scholarly practitioners attend to the politics of change and cultivate the goodwill and engagement of the individuals responsible for implementing the change efforts. The authors posited the Plan-Do-Study-Act Cycle as a means for identifying and testing a theory of improvement, gathering and analyzing data to compare predictions to results, and using that knowledge to move forward in an iterative cycle until the desired change is achieved. Appendix B provides the Plan-Do-Study Act cycle based on this intervention plan.

3.6 Methods and Measures

Bryk at al. (2016) recommended intertwining a system of measures into the PDSA cycle to create "a strong empirical infrastructure for learning their way into better outcomes" (p. 139). Several different types of measures provide evidence of change ideas at different levels in a system. Outcome measures show how a system is performing and are described as leading (micro-level) or lagging (macro-level). Driver measures are linked to outcomes and indicate how the theory of improvement is working. Process measures give evidence of the change idea quickly and efficiently. Balance measures consider the whole system and show how the change idea impacts other parts of the system. Mintrop (2016) called for scholars to identify a unit of analysis (subject or entity) that gives the most information about the effect of their intervention. This will drive the decision as to what kind of data collection should take place (Perry, Zambo, & Crow, 2020).

Practical measures function to assess whether the change idea is actually working, and then to predict how the change affects individuals to set priorities for future work (Yeager et al., 2020). They should provide affordances for direct measurement of targets and lead to greater specificity. In addition, they should be based in language and experiences common to the individuals implementing the change and embedded in the constraints of the work at hand. For this PDSA cycle, I collected data through surveys, artifact analysis, and interviews. A mixed methods approach consisting of quantitative and qualitative measures was applied for data collection by including Likert scale and open-ended survey responses, Likert scale-based lesson plan analysis, and thematic coding of interview responses. Table 3 illustrates the link between change ideas, questions resulting from each idea, the data source or unit of analysis, and the type of measure it addresses. In this study, pre-survey and post-survey results and post-intervention interviews were used to evaluate changes in the driver measures. Post-survey results and interviews offered data regarding the process measures, which indicate the specificity of change. Lesson plan artifacts are certainly a measure of leading outcomes but also serve as a process measure. The post-intervention interview can be a rich source to understand the effects on leading outcomes, drivers, and perhaps more systemic balance measures.

Table 3. Changes, Data, and Measures

Change Idea	Question	Data Source	Type of Measure
Training on STEAM pedagogy and conceptual Framework	What do teachers in my district report as their STEAM teaching efficacy before and after a professional development intervention on STEAM integration? In what ways do they incorporate pedagogy into their lesson plans?	Pre-Survey Post-survey Lesson Plan Artifacts	Driver Driver Process
Examine PA Career Readiness Standards	Will teachers gain knowledge of Career Standards and be able to integrate them into lesson plans?	Pre-Survey Post-Survey Lesson Plan Artifacts	Driver Driver, Process Leading Outcomes
Identify and explore 21st-century skills	Do teachers incorporate affordances to develop 21st-century skills in their lesson plans?	Lesson Plan Artifacts	Leading Outcomes
Lesson plan study and development using lesson plan template	In what ways do elementary in- service teachers in my district integrate a conceptual model of STEAM teaching practices as defined by Quigley, Herro, & Jamil (2017) into their lesson planning?	Lesson Plan Artifacts	Leading Outcomes
Collaborative time during Professional Learning Community to discuss implementation	What additional supports do teachers identify as necessary for STEAM/Career lesson plan development and implementation.	Interviews	Driver, Leading Outcome, Balance

Due to the complex nature of teaching environments, it was important to collect multiple and varied sources to document the process of learning and conduct retrospective analyses (Cobb et al., 2003; Schoenfeld, 2006). Brown (1992) recognized the difficulty in attempting to capture the "tapestry of social and intellectual discourse to truly quantify real concept or affective change taking place over time" (p. 163). A mixed methods analysis added rigor to the process and helped to distinguish elements that result from accidental or secondary elements. Triangulating the data makes certain that multiple methods address each research question to enhance the trustworthiness of the findings. The data on this intervention came from surveys given before and after the professional development sessions, analysis of lesson plan artifacts, and interview responses from participating teachers. Table 4 illustrates the connection between research questions and data sources. Multiple measures address each of the research questions, with the last question driving future iterations of the PDSA cycle.

3.6.1 Surveys

Surveys are a valuable tool for the scholar practitioner. Bryk et al. (2016) recommended that those working with the improvement science model begin by learning quickly about the system and stakeholders affected by the change. The authors suggested that researchers proceed in a minimally intrusive manner while gathering empirical data that can be analyzed to develop iterative cycles of small tests of change. With recent advances in technology, online surveys are easily accessible to respondents yet relatively straightforward for a developer to create, administer, and analyze. Mintrop (2016) stated that "research design that accompanies the intervention (should consist) of both impact and process data to pick up outcomes and document fluid change process" (p. 165). In this way, researchers can measure behavior changes in a potentially unbiased manner.

Research Questions	Pre-session survey- demographics and experience with STEAM-	Post PD evaluation survey	Lesson plan artifacts	Interviews
What do in-service teachers in my district report as their STEAM teaching efficacy before and after a professional development intervention on STEAM integration?	Х	Х	Х	Х
In what ways do in-service teachers in my district integrate a conceptual model of STEAM teaching practices as defined by Quigley, Herro, & Jamil (2017) into their lesson planning?			Х	Х
What do in-service teachers in my district identify as additional supports that will assist them in implementing these lesson plans?		Х		Х

Table 4. Triangulation Matrix

Pre- and post-intervention surveys are an excellent way to gather qualitative and quantitative data about the effects of an intervention. Menter et al. (2011, p. 105) referred to the flexible nature of surveys to gather a wide range of information about attitudes, values, beliefs, and behaviors. The authors, however, cautioned that surveys are easy to administer but difficult to design. Disadvantages to surveys include the consideration of non-responders in data analysis and the fact that some surveys that require self-reporting may be affected by the respondent's motivation, honesty, memory, ability, or interpretation of the questions. For example, participants may not interpret STEAM from the same framework used in this study when asked to rank their

knowledge about STEAM resources and strategies. In addition, participants may have a preconceived or incomplete understanding of the term 21st-century process skills. Therefore, survey questions clarified these terms.

Research indicates that teacher self-efficacy related to STEAM education is influenced by teachers' content knowledge, experience, and pedagogical content knowledge (Stohlman, Moore, & Roehrig, 2012). Several surveys used in STEAM or STEM research measure feelings of efficacy for STEAM integration. Major categories for these instruments include references to context, teacher attitudes and beliefs about their own efficacy, perceived challenges, knowledge of integrated STEM models, and demographic factors (Mobley, 2015). Prior to this PD intervention, teachers completed a survey to determine demographics such as teaching experience, educational level and background, and prior experiences with STEAM professional development. The survey was developed using Qualtrics Survey Software (www.qualtrics.com) and incorporated Likert scale items to measure participant understanding of STEAM concepts, and attitudes towards and feelings of efficacy in STEAM integration, career readiness standards, and 21st-century skill development.

Margot and Kettler (2019) reviewed 25 articles dealing with teachers' perceptions of STEM integration, including several that involved professional development experiences. This source provided information about the different combinations of measures and tools used by researchers in the field. I made adaptations to relevant surveys to create the survey used for this study (Asghar et al., 2012; DeJarnette, 2018; Herro & Quigley, 2017; Hsu, Purzer, & Cardella , 2011; Hunter-Doniger & Sydow, 2016; Jamil, Linder, & Stegelin, 2018; Mobley, 2015; Nadelson et al., 2012; Nadelson et al., 2013; Srikoom, Faikhamta, & Hamuscin, 2018). See Appendices B

and C for the Pre-PD Survey and Post- PD Survey. The quantitative data were subjected to paired t-tests to analyze before and after responses.

3.6.2 Artifact Analysis

Artifact or document analysis can offer evidence related to the success or failure of a change idea. This evidence can be quantitative and represent numerical or categorical information related to the frequency of content. In addition, Bowen (2009) considered documents a source of qualitative data through careful content analysis that can reveal themes and categories for more descriptive data. As a tool for triangulating data, document or artifact analysis can provide additional evidence to support a claim and add credibility to a study (Bowen, 2009). In this study, the lesson plans developed by participants in the TIW summer professional development provided valuable data regarding the following research question: In what ways do elementary in-service teachers in my district integrate process skills and career standards and a conceptual model of STEAM teaching practices as defined by Quigley, Herro, and Jamil (2017) into their lesson planning?

Lesson plans are both unique and valuable in that they provide insight into the instructional and curricular preferences of teachers (Sias et al., 2017). Table 8 shows the essential components utilized to create the lesson plan rubric. I developed a rubric to evaluate the artifacts based on the STEAM principles that corresponded to the conceptual model developed by Quigley, Herro. and Jamil (2017). The rubric provides descriptors for indicators of each of the six STEAM principles that categorize implementation at four different levels of success based on lesson plan analysis in an additional study of STEAM enactment (Quigley et al., 2020). An additional category monitored how PA Career Standards were integrated as a part of the Teachers in the Workforce (TIW) grant

requirements. (See Appendix D for this rubric.) The rubric and descriptors were reviewed by Dr. Quigley, one of the developers of the conceptual model. The complete rubric used Qualtrics software, which provides both narrative and numerical data with a Likert scale to provide for quantitative and qualitative analysis mechanisms.

Category		Description		
Problem-Based Approach		Sets students up to solve authentic problems like those they might need to solve outside of the classroom or in the community.		
	Curriculum Standards Integration	Gives students opportunities to use multiple content area skills to complete assignments or activities		
Career Skills Integration		Lesson contained connection to STEM related job and career skills		
21st-Century Skill Development		Higher order skills beyond memorization or application of simple procedures, such as constructing and organizing knowledge, critical thinking, problem solving, conduct and solve inquiry activities, collaborate with others, think creatively, and persistence		
Technology Integration		Student learning is enhanced through technology allowing them to become creators and not just consumers		
Authentic Tasks		Students address relevant, community or real-world issues as they apply knowledge or skills to come up with solutions		
Inquiry/Student Choice		Providing students opportunities to direct their own learning and have choice over process and product		

Table 5. Lesson Plan Analysis Categories

3.6.3 Interviews and Open-ended Survey Responses

Qualitative interviews are unique in offering a depth of information about the perceptions and experiences of the actors involved in a change effort (Tierney & Dilley, 2002). Tierney and Dilley (2002) made four suggestions to enhance qualitative interviews. First, study background theory and information related to the interview. Then, observe and analyze other interviews, going beyond research interviews to consider journalistic interviews as well. They recommended creating protocol questions as a guide and landmarks along the path an interview may take to keep things on track but recommends that interviewers be open to revising that protocol as experience indicates. Finally, the authors suggested that practitioners engage in self-reflexive interviewing in different contexts to get comfortable with multiple voices and to develop listening skills. Wang and Ying (2012) called for researchers to be mindful of the covert power of the traditional researcher-directed interview, which can convey a hierarchical relationship between the interviewer and the responder. They cautioned researchers to examine their protocol questions for clarity of topic and the likelihood that they will invite elaboration and context descriptions. They also reminded researchers to review questions for the presence of presuppositions and bias.

Several researchers have used pre- and/or post-intervention interviews to assess the effectiveness of a professional development experience or to inform future support for STEAM integration (DeJarnette, 2018; Herro & Quigley, 2017; Kim & Bolger, 2017; Lesseig et al., 2016). Those articles helped inform the scope of the interview protocol questions listed below, although grounded theory suggests that early data analysis may inform iterations of interview questions (Charmaz & Belgrave, 2012). A constructivist approach to grounded theory recognizes that gaining meaning from interviews implies that interview questions need to range from "sufficiently general to cover a wide range of experiences and narrow enough to elicit and explore the participant's experience" (Charmaz & Belgrave, 2012, p. 351). By preparing main questions, followed by follow-up and probing questions, the interviewer can solicit more information from

the respondent (Rubin & Rubin, 2012). Table 6 illustrates how interview questions address the research questions in this study.

Research Question	Interview Question	Measure
What do in-service elementary teachers in my district report as their STEAM teaching efficacy before and after a professional development intervention on STEAM integration?	How would you describe STEAM integration to another teacher? Would you feel confident explaining STEAM integration to your colleagues?	Driver Driver
In what ways do elementary in- service teachers in my district integrate, process skills and career standards, and a conceptual model of STEAM teaching practices as defined by Quigley, Herro, & Jamil (2017) into their lesson planning?	Describe how the Teachers in the Workforce Summer PD has impacted your classroom practice. What takeaways from this summer worked well in your classroom practice?	Leading Outcome Leading Outcome
What do elementary in-service teachers in my district identify as additional supports that will assist	What is the most difficult part of implementing the STEAM/Career Readiness lessons in your classroom?	Process, Balance
them in implementing these lesson plans?	What would help you be more effective at integrating the	Lagging Outcome
Franci.	STEAM/Career Readiness lessons? What other supports or information would you like?	Balance

Table 6. Interview Question Correlation

All interviews were recorded using the Steno app (https://www.stenoapp.com/). I took field notes and scheduled time after each interview to jot down the conditions and impressions of the interview. I transcribed the audio by hand while relying on the STENO transcription to check for accuracy as soon as possible after the interview. Poland (2002) referred to challenges to transcription quality that may include recording quality as well as misinterpretations of the transcriber or transcription software that can cause punctuation errors, word substitution, or incorrect phrasing. He recommended using a transcription notation system (p. 639) to capture the nuances of the conversation if necessary. Merriman recommended that researchers undergo

simultaneous data collection and analysis by basing iterative data collection sessions on lessons or themes that organically arise from earlier ones (2009, p. 172), so reviewing the text of interviews served to inform future questioning.

I used Voyant tools (htps://voyant-tools.org), a web-based text analysis tool to scan the transcripts of reflection interviews with individual teachers. This software quantified term usage as a first step to suggest themes in the responses regarding additional supports needed for successful STEAM integration. Hammerness et al. (2005) advanced a framework for teacher learning to support teachers in becoming adaptive experts to move into the innovative dimension. The framework (p. 386) organizes teacher learning in a community of practice into five areas, beginning with *Vison*, or "images of the possible"; *Understanding* or deeper knowledge of content and contexts; *Dispositions*, or habits of thinking; *Practices* that support these beliefs; and *Tools* or resources to accompany this vision. The framework is situated within a professional learning community and acknowledges the interplay between community and elements. I used this framework to identify broader themes in the survey responses and interview transcripts. Chi (1997) recommended coding data twice and said that the second consideration of transcript data to confirm categorization codes can add validity to a study.

I had hoped to interview a representative sample that characterized a cross-section of the participants based on grade level bands. My plan was to interview three to five teachers by the end of November, although pandemic considerations pushed this timeline back. This kept my PDSA cycle close to the 90-day recommendation. The effects of the pandemic altered this timeline slightly. A pre-survey was administered digitally at the beginning of the three-day experience, with the posttest survey similarly administered at the end of the workshop. Artifact analysis of lesson plans continued throughout the fall of 2020 and into the winter of 2021. Interviews were conducted

during the 2020-2021 school year, dependent on lesson development and implementation. I developed the interview questions based on interviews used by researchers in the field (Du et al, 2019; Herro & Quigley, 2017; Jamil, Linder, & Stegelin, 2018). The questions I used were also responsive to interactions during the PD sessions.

4.0 PDSA Results

4.1 Data Collection

This chapter examines the data gathered to evaluate the effect that one professional learning experience had on a small group of educators. I considered data from three sources: pre-and postintervention surveys, interviews with three teachers, and analysis of lesson plan artifacts. The data included quantitative and qualitative measures to formulate a complete understanding of the participants' attitudes and understandings. Questionnaires are a good way to determine and compare changes in perceptions, but interviews allow for a greater understanding of the topics and the nuanced responses of the subjects (Bernhardt, 2004). Lesson plans or teacher-designed curricula can both develop and measure STEAM teaching capacity (Kang, 2019; Quigley, Herro, & Baker, 2019).

Three interviews conducted during the expected implementation period helped me to assess changes in feelings of efficacy and to clarify the challenges educators faced during lesson development and implementation to inform future PDSA cycles. The three subjects represent demographic differences as well as implementation levels. These interviewees teach various content at the primary, intermediate, and junior high school levels. One was not able to complete a lesson plan and asked for assistance in meeting that goal. Another turned in a timeline and vague plan that did not use the planning template provided during the PD session. The last teacher had a well-developed plan and adapted the lesson to implement it while the district was providing only remote instruction. The participants submitted nine lesson plans, some formed by teams of two to four teachers. Some participants did not submit complete lesson plans. The teaching context for some of these teachers shifted over the 2020-2021school year as the district converted from primarily virtual to hybrid and then mainly in-person instruction models. The demands of preparing for virtual and then in-person instruction that adhered to COVID-related classroom restrictions created a myriad of challenges for teachers that took priority over TIW lesson plans.

4.1.1 Participant Data

Nineteen teachers participated in the PD experience. In general, the group consisted of seasoned teachers with a generally high level of professional training and education. Hammerness et al. (2005) utilized the term adaptive expertise and stated that teachers must develop a level of efficiency in their practice to allow for innovation. However, the authors addressed the paradox inherent in adapting innovative strategies in the classroom in that teachers become less effective initially as they replace comfortable routines with new ones. That can deter the willingness to adopt new ways of teaching and learning. Therefore, I felt it relevant to include demographics regarding both the years of experience (Table 7) and the education levels achieved by the participants (Table 8).

Years of Teaching Experience	Presurvey (n= 19)	Post- Survey $(n=15)$
0-5 years	2	0
6-10 years	2	3
11-15 years	5	3

Table 7. Teaching Experience of Pre- and Post-survey Participants

Table 7 continued

16-20 years	3	3
20 + years	7	6
Total	19	15

The participants represented a broad sample of both grade levels and content areas. Several of the participants teach across multiple grade levels. For example, two of the participants were guidance counselors who regularly collaborate with classroom teachers in grades K-6 in both elementary school buildings and teach classes to students as part of their weekly schedule. Both guidance counselors are members of the TIW Grant team and are responsible for integrating and documenting the PA Career Standards Goals. One participant teaches Food and Consumer Science along with supporting ESL students K-12. Another is the Gifted teacher who serves students in grades 7-12 while also teaching an AP Biology class and a Robotics class that is part of the Junior/Senior High School STEAM rotation. Three participants were special education teachers representing K-3, 4-6, and Life Skills 7-12.

Highest Level of Education Attained	Pre-Survey (<i>n</i> = 19)	Post-survey $(n = 14)$
4-year degree in education field, coursework for additional certification	2	1
Master's degree in educational field	11	7
Master's degree plus coursework for additional certification	6	6

Table 8. Education Levels of Participants

STEM and/or STEAM integration is often considered the domain of science and math instruction. However, the participants represented a broad field of content and grade levels. This district organizes teachers into two K-6 elementary level buildings and a third building that houses students from grades 7-12, divided into a junior high (grades 7 and 8) and senior high (grades 9-12). The district has attempted to create a middle school culture to support students who may struggle to succeed after elementary school by creating a Junior High School Team and a STEAM program that includes mandatory rotations and electives. Due to the district's small size, teachers often cross between subject areas and grade levels, teaching both senior and junior high students. At the elementary level, teachers in grades K-3 usually are required to teach all subjects to a homeroom class, while teachers in grades 4, 5, and 6 often organize into departmentalized classes, teaching perhaps science and math or language arts and social studies.

Notably, only one participant teaches math to grades 7 and 8, and only two participants teach science and STEM or STEAM-related classes at the junior /senior high school level. A majority of the teachers taught English/Language Arts, either solely or as a part of their day in a self-contained classroom. Cook et al. (2020) found that, to many teachers, literature can be a natural entryway to integrate STEAM instruction. However, the practice of STEAM integration was new and unfamiliar to the majority of the teachers involved in the lesson planning activity, especially those who primarily taught English or reading.



Figure 4. Content Areas Taught by Participants

STEAM professional development is effective at transforming the knowledge, abilities, and attitudes of teachers at all levels of experience (Herro & Quigley, 2017). Other studies suggest that such changes develop over time and with increased exposure to STEM related PD (Margot & Ketler, 2019). For this reason, I thought it was valuable to determine the amount of STEAM-related professional learning experiences participants had before this experience, specified in Table 9. Only one person reported having *a lot* of prior STEAM PD. The majority of participants in the pre-survey (79%) had little to no professional development experiences related to STEAM instruction. The responses offered (*none at all, a little, a moderate amount, a lot , a great deal*) are subjective and relied on the participants to interpret the scale. Menter et al. (2011) pointed to disadvantages of self-reported surveys that include relying on the participants' interpretation, memory, motivation, and honesty.
Exposure to STEAM related PD	Count
None at all	3
A little	12
A moderate amount	3
A lot	1
A great deal	0

Table 9. Prior STEAM PD Experiences

Nineteen participants took the pre-survey as a part of the opening activities, so participation was 100 percent. I shared the post-survey via email after the training sessions ended. All teachers completed the pre-survey, although only 15 completed the post-survey. This is a completion rate of 79 percent; a response rate of above 60 percent is considered adequate to represent the total sample (Bernhardt, 2004). In some instances, I considered the results of both pre- and post-surveys together while, at other times, I filtered the data to consider differences between pre- and post-survey data. I combined questions to create Likert scale data and used descriptive statistic measures to calculate the mean and p value to determine significance and to avoid the difficulties associated with understanding ordinal Likert scale data (Boone& Boone, 2012).

4.2 Research Question 1: Effects on Teacher Efficacy

4.2.1 Survey Data

To answer this question, I considered the data found in the component of the pre- and postsurvey regarding STEAM education as well as teacher interviews. I filtered the survey data to consider only the responses of participants who completed both surveys. This approach helped to address the research question *What do in-service teachers in my district report as their STEAM teaching efficacy before and after a professional development intervention on STEAM integration?* Because successful STEAM integration relies on an interrelationship between teachers' disciplinary content knowledge, pedagogic knowledge, motivation, and feelings of efficacy (Nadelson et al., 2013), I included several questions that address this intersectionality. For example, questions 1 and 6 (I understand what integrated STEAM education means and I am knowledgeable about STEAM resources and strategies) both relate to pedagogic content knowledge about the particularities of STEAM integration.

The increase between pre- and post-survey data reported in Table 10 shows that the PD did increase educators' understanding of the methods, tools, and resources that distinguish STEAM education. The findings also indicate an increase in positive attitudes regarding the value of STEAM education. Question 4 (*I believe that STEAM integration within my curriculum is valuable for my students*) measures each educator's attitude towards STEAM education. This question showed the highest gain (+0.92), indicating that the PD intervention was successful in building teachers "buy-in" of the value of STEAM integration. Questions 2 and 3 had a positive mean difference (+0.75 and +0.74), indicating that teachers felt more efficacious after the PD about planning and implementing a STEAM unit. However, this finding contradicted the responses to

question 5 (*I believe that incorporating STEAM integration is within my reach currently*), which showed a decrease (-0.08). When considered in the context of the shift to virtual teaching for the first semester, this response makes more sense. Teachers may have had concerns about immediate implementation while they adjusted to online instruction.

Number	Question	Pre- Survey mean	Post-survey mean	Differences	P value=
Q1	I understand what integrated STEAM education means.	2.53	3.57	+1.54	.00089
Q2	I am comfortable planning integrated STEAM activities for my students.	2.32	3.07	+ 0.75	.02593
Q3	I am comfortable implementing integrating STEAM activities for my students.	2.47	3.21	+ 0.74	.17080
Q4	I believe that STEAM integration within my curriculum is valuable for my students.	3.58	4.50	+ 0.92	.27348
Q5	I believe that incorporating STEAM integration in my curriculum is within my reach currently.	3.58	3.50	-0.08	.58449
Q6	I am knowledgeable about strategies and resources for STEAM integration.	2.21	3.0	+0.79	.00607
Q7	I would need additional support to incorporate STEAM integration into my classroom.	3.58	2.64	-0.94	.00453

Table 10. Pre- and Post-survey Comparison

Bandura (1986, in Woolfolk, 1998) differentiated between efficacy expectations, the individual's internal convictions regarding their ability to orchestrate a task, and outcome expectations, the individual's feelings about the consequences of performing the task with competence. Questions 2 and 3 address efficacy expectations, and Question 5 touches on outcome expectations. While questions 2 and 3 (*I am comfortable planning integrated STEAM activities for my students* and *I am comfortable implementing integrated STEAM activities with my students*) showed a significant increase, question 5 (*I believe incorporating STEAM integration is within my reach currently*) did not. This is not surprising considering the vast shifts in teaching contexts brought on during the pandemic beginning in March 2020 and continuing into 2021.

These figures indicate that teachers' sense of efficacy increased as a result of the PD intervention. Post-survey results illustrate a decrease in responses of "Not at all" and "A little" as self-assessments of efficacy. It is also apparent that the participants value STEAM education and increased their understanding of STEAM integrated teaching. This is not unexpected, as a major intent of the intervention was to introduce the conceptual STEAM teaching module based on the work of Quigley, Herro, and Jamil (2017). This result shows that participants felt more comfortable planning and implementing STEAM integration, and more knowledgeable about STEAM resources, after the PD session. In summary, survey responses revealed that participants' attitudes, understanding, and knowledge about STEAM integration increased, but they still had questions about actual classroom enactment.

4.2.2 Teacher Interviews

Teacher interviews yielded similar results. The first subject, David, has been teaching for over 20 years and has spent the last 10 years teaching mainly fifth-grade social studies and Language Arts. This year he has a self-contained classroom and is teaching all subjects. Although David values STEAM and found the professional development experience helpful, he has not formulated a lesson plan. He cited the demands and constraints of teaching remotely and then in a hybrid model and said that he felt the idea he had during the training was not possible this year. He said that prior to the TIW PD, he had experiences with STEAM PD but had trouble envisioning ways to integrate it into Language Arts meaningfully. He described STEAM as a "hands-on practical type of learning" in which students "integrate all those areas to really apply your knowledge to a particular task or problem like PBL." He said that his prior PD experiences with STEAM did not seem to produce valuable learning activities. The PD experience did have a positive effect on him, and he felt that he wanted to include STEAM into his plan for the year, but he had been unable to due to constraints brought on by COVID-19: "If things were normal, I know I could do it." He also said that he could easily formulate a whole STEAM unit.

Erin teaches seventh and eighth grade math and is the Junior High School Team leader. The middle school has what the district labels a STEAM program that includes a seventh grade rotation through classes that include physical computation with Micro bits and Knex, movie making, a human centered design project, and CS Discoveries coding course. Eighth grade STEAM electives include an introduction to STEAM innovations, animation with ALICE, STEAM competition course, and Robotics. Erin stated that the TIW PD had resulted in a shift in her understanding of STEAM integration from one that focused on using technology, including coding, to a broader conception of using technology to support problem solving "like open ended types of situations for teaching and letting kids kind of guide where things go." She said that she had been "intimidated by anything that said STEAM" before the PD but had a better understanding now. She felt it would be ideal to have "the kids working on one project through their whole day but using the resources in the room (discipline-centered classes) at that time." She also felt that incorporating the arts into STEM makes it more approachable and shifts the emphasis to communicating and creating to use math and apply science and other skills. She described STEAM education as both a mindset and a style of teaching. She said that this was her first exposure to STEAM PD and that she was less intimidated now and could use what she learned as "access" to integrating STEAM.

Patty has been teaching second grade for 18 years. As a mother of two students in a neighboring district with a well-developed STEM program, she had prioritized integrating more STEM activities into her classroom last year and chose to study STEM integration with a district Professional Learning Community "before COVID hit." She was enthusiastic about the unit she taught and found that her students were engaged and motivated, although she cited limitations with implementation during remote instruction. She reflected on improvements moving forward, like including an engineering component and more technology integration. She stated that she needs to "do more project-based learning with the kids" and that "they would pick up those skills a lot faster if we could make them applicable so they can use them in real life." She was eager to design more STEAM units and confident about her ability to plan more lessons in the future.

4.2.3 Summary

In summary, one facet of this research was to evaluate the effect a professional development intervention on STEAM integration had on teachers' feelings of efficacy towards designing and implementing integrated STEAM education into their classroom practice. A null hypothesis would assume that there would be no change in teacher efficacy as measured by survey and interview responses. Analysis of variations in survey responses before and after the

professional learning experiences indicates that the participants reported increases in their understanding of STEAM education as described in one conceptual model (Quigley, Herro, & Jamil, 2017). In addition, the intervention resulted in a slight increase in teachers' attitudes towards and willingness to plan to integrate STEAM education into classroom practice.

4.3 Research Question 2: Lesson Plan Analysis Data

A secondary goal of this study was to consider how teachers integrated STEAM principles into their lesson plans after this targeted professional learning experience. *In what ways do inservice teachers integrate process skills, career standards, and a conceptual model of STEAM teaching practices as defined by Quigley, Herro, and Jamil (2017) into their lesson plans?* Nine lesson or unit plan documents were submitted to the grant team for review. The rubric offers narrative data about each lesson plan by providing descriptors for indicators of each of six STEAM principles that categorizes implementation in each area at four different levels. (See Appendix E for a copy of this rubric.) Table 11 presents each lesson analysis using the descriptor categories.

The rubric assigns each artifact a numerical score in the six categories using these descriptors. These data were strictly ordinal, meaning that it is based on observations of degree, but falls under Likert response items (Boone & Boone, 2012). The scores are reported in Table 11 to indicate how well teacher lesson plans collectively incorporated the elements of the STEAM conceptual model developed by Quigley, Herro, and Jamil (2017). Appendix F provides a complete analysis with each descriptor rating for each lesson plan.

4.3.1 Problem Scenario

Teachers were moderately successful in grounding the lesson in a problem scenario with a mean of 2.80 and a variance of .16, but the problems were often irrelevant to students' lives or did not require students to generate solutions to the problem. Only three unit plans scored at the highest level. A second-grade unit plan asked students to suggest ways to limit flooding of a park that runs adjacent to a local stream, while another lesson plan presented students with the challenge of designing a way to protect members of a local rowing club from collisions on their early morning practice sessions. A 7-12 special education teacher's lesson plan was based on supporting biodiversity in light of changing world conditions. The four lesson plans designed at the senior high school level focused on exploring STEM careers and not on actual problem scenarios.

STEAM Principle	Mean	STD Deviation	Variance	
Problem Scenario	2.80	1.08	1.16	
Discipline Integration	2.10	0.70	0.49	
Career Standards integration	2.90	0.70	0.49	
21st-century skill development	2.50	0.90	0.81	
Technology Integration	2.90	0.70	0.49	
Authentic Tasks	2.80	0.60	0.36	
Student choice	2.10	0.70	0.49	

Table 11. Lesson Plan Analysis Quantitative Summary N=9

4.3.2 Discipline Integration

An integrated approach to curriculum development is recognized as a way to make content from multiple disciplines more coherent and relevant to students (Kim & Bolger, 2015; Quigley, Herro & Baker, 2019). However, there are mixed approaches to what integration can look like, including transdisciplinary, interdisciplinary, multi-disciplinary, and cross-disciplinary (Perignat, 2019, Shernoff et al., 2017). Teachers were less successful at discipline integration as rated by the researcher with a mean score of 2.10 and a low variance of 0.49., with no lesson plan meeting the highest competency by offering opportunities for students to encounter and use knowledge or skills from multiple STEAM content areas and apply them to solving problems. Two high school lessons, a career cluster investigation and planner use unit, called for knowledge or resources from only one content area. Five of the unit plans attempted to connect with resources from another STEM discipline, and three were successful at incorporating content across STEAM disciplines. For example, a lesson plan developed by seventh grade science, math, and ELA teachers addressed standards within each of those disciplines by assigning students to read articles about variations in candy production and then analyze and present data related to proportions and ratios of various ingredients. Teachers often lack an understanding of transdisciplinarity and how adding the A for Arts integration can be accomplished (Herro & Quigley, 2017; Quigley, Herro, & Jamil, 2016).

4.3.3 Career Standard Integration

A primary requirement of the TIW grant work was to introduce students to STEM careers or provide opportunities to utilize skills that may prepare them for work in a STEM career. All nine lessons connected in some way to career skills with an average ranking of 2.90 and a minimum score of 2.0, although two received the highest rating for relating the STEM career skills as applied to a particular problem or realistic application. Three lesson plans focused solely on having students research STEM careers directly, while others included interaction with STEM career applications or STEM professionals relevant to the problem scenario. The second-grade creek flooding problem includes opportunities for students to talk to a local engineer, and the biodiversity unit incorporated opportunities to investigate the role of zookeepers and other jobs in animal conservation fields.

I defined 21st-century skills as higher order skills beyond memorization or application of simple procedures, including critical thinking, problem-solving, self-directed inquiry, collaboration, and creative application of knowledge. The bulk of the lesson plans (seven) offered limited opportunities to practice these skills, with a mean of 2.5 and a variance of 0.81. At the time of lesson development, pandemic guidelines stipulated that students maintain social distancing requirements for in-person learning or collaborate across virtual spaces. However, three lesson plans (Community Flooding Solutions, Light and Sound Challenge, and Maintaining Biodiversity) called for students to work in teams to design solutions to the problem scenario. The first-grade lesson presented students with the challenge of building an actual prototype for a device that would keep rowers safe on the river, which calls for designing and modeling creative skills (Quigley, Herro, & Jamil, 2017).

4.3.4 Technology Integration

Technology integration is an important component of the STEAM conceptual model and connects to the development of 21st-century skills. Teachers were successful at integrating some form of technology into their lesson plans as an instructional tool and as a way for students to respond or communicate. The Candy Analysis and Creation unit required students to learn and use Excel for data analysis, and students used SeeSaw to share their solutions for the second grade Flooding unit However, only one lesson plan, the Maintaining Biodiversity unit, allowed students to explore different technological tools to communicate their solutions by creating a blog, a presentation for a government agency or zoo, or a model of the enclosure or habitat.

4.3.5 Authentic Task Integration

Authentic tasks help students connect what they are learning to real-world issues or careers. The lesson analysis yielded an average score of 2.80 with a low variance of 0.36. Several lesson plans incorporated authentic tasks such as suggesting changes to a local park to reduce flooding, prototyping a device to install on a kayak, or designing a habitat for an animal at a zoo or reserve. Many of the high school level lessons required students to research STEM careers or careers of interest, but these lessons were not grounded in a problem scenario. This resulted in relatively higher rankings in this category, although they did not align well with the STEAM conceptual model.

4.3.6 Opportunities for Student Choice

Student choice refers to the capacity students have to direct their learning about the topic and the freedom they have to determine a product that demonstrates their understanding of the content presented. None of the lesson plans ranked at the top competency in the evaluation rubric, with a lower average of 2.10 and a variance of 0.49. The majority of the lessons (seven) offered students no choice or limited opportunities in either the process for learning or in product creation. Again, the second grade Community Flooding Solutions was designed to allow students to pursue a variety of solutions to a community problem and come up with suggestions for local authorities. However, their presentations were limited to drawings posted in a SeeSaw account. Although some of the high school level lessons allowed students to choose a career or career cluster to investigate, their products were limited to posters, Power Points, or research papers.

4.3.7 Lesson Plan Analysis Summary

In summary, the statistical information presented in Table 9 showed that teachers were fairly successful at Technology and Career Standards integration with a mean of 2.90 and a variance of .49. The teacher lesson plans showed lower scores in Discipline Integration and Student Choice with a mean of 2.10 and a variance of .70. Teacher-developed lesson plans showed the greatest variance in the Problem Based area, which meant that some teachers struggled to ground the unit in a relevant and engaging problem, while others presented a fairly relevant or well-developed scenario for students to engage in. Scores for authentic tasks support the finding that most teachers developed problem scenarios that did not connect to community issues or create opportunities for students to apply content knowledge to real-world tasks. These findings contradict the increases in teachers' feelings of efficacy at planning and integrating STEAM activities considered in Research Question 1. It is important to note that measures of self-efficacy do not always correlate positively with level of competence, mainly because people tend to overestimate or underestimate their abilities (Woolfolk, 1998).

4.4 Research Question 3: Additional Supports Needed for Implementation

4.4.1 Open-ended Survey Data

This study considered a third research question: *What do in-service teachers identify as additional supports to assist them in planning and implementing integrated STEAM lesson plans?* Responses from an open-ended question on the post-survey and interview responses provided the data for this query. I evaluated the data using inductive methods, including thematic content analysis to search for patterns and themes across the text of each interview and open-ended response. I first entered the open-ended responses from post-survey question (*What additional supports beyond this professional learning experience might help you incorporate STEAM integration?*) into Voyant software to help me visualize and suggest terms and frequencies. I used these words to sort each text phrases or fragments into subheadings. My next step was to review the data in terms of the broader conceptual framework proposed by Hammerness et al. (2005), which organizes professional development for innovating practice into five areas: vision, understanding, dispositions, practices, and tools. This framework helped me identify broader themes within the data, as illustrated in Table 12.

Themes	Sub-themes	Codes	
Understanding STEAM education- Vision Understanding	Continuous or consistent support	"Ongoing updates and professional development" "More time to take more sessions" "Ongoing updates and support" "Ongoing updates" "Up-date and educate the educators" "Additional STEAM training in STEAM integration" "Thinking outside the box re STEAM" "Connecting real life examples to the classroom" "I'd like to see research/proof as to how it benefits students after high school"	
Examining practice of STEAM	Observing Examples	 "Seeing how it is incorporated in all subject areas" "Observing teachers doing STEAM activities" "Materials and examples of how others have used it" "Connecting real life examples to the classroom" 	
education Practices	Implementing	"To discuss implementation styles"	
Tools	Resources-tools	"Improved tech resources" "STEAM materials and how to use them" "Using field trips or guest speakers, You Tube" "Find resources" "Communication with community resources"	
Working within a learning community <i>Dispositions</i>	Coaching Collaborating and peer planning	"Help me develop lessons that I can use in my classroom" "Collaborative time" "Collaborating with peers" "More time to collaborate with colleagues" "Continued meeting with the group" "I feel that additional time collaborating with STEAM based educators in a more one to one setting would be most useful to me"	

Table 12. Thematic Coding of Open-Ended Survey Responses

This data is consistent with research that suggests that many teachers struggle with a conceptual understanding of STEAM (Herro & Quigley, 2016; Quigley & Herro, 2019; Son et al., 2012). Nine teachers felt they needed more information on STEAM integration, which indicates a lack of understanding. Eight teachers felt that they needed support falling under the category of

examining STEAM education in practice through observation, examples, discussion, or shared resources. Collaboration also emerged as a theme directly mentioned by the teachers, to plan together or meet during implementation.

4.4.2 Interview Data

Interview data supported these findings as well, as reported in Table 13. David said that he was interested in integrating STEAM into his curriculum, "if I worked with it a little bit more." David did mention that he was concerned about making certain that his students were prepared for the PSSA (Pennsylvania State Standardized Assessments). He mentioned needing a better understanding of STEAM and how to execute it, time and assistance for planning, and opportunities to co-plan or even co-teach at first. He also felt that administrative support and follow-through would be important for successful implementation across all grade levels.

Erin, the middle school math teacher, spoke of several barriers to integrating STEAM education, such as pressure relating to "content and standards and textbooks that we are supposed to be using." She felt that parent support would be important, which would hinge on parents' understanding of assessment measures and work processes associated with the STEAM conceptual model. She also had apprehensions about student engagement and accountability. She talked about the need for more planning time with the middle school team to "weave it together a little better so that it is clear that you are using your skills from different classes to accomplish one goal". Erin had concerns with students' ability to focus, stay organized, and direct their learning but thought that it was possible if STEAM was a district focus so that students build those skills in the earlier grades.

Themes	Text			
Understanding STEAM education	Pete- "I haven't worked with it enough, so I'd need a little more reading."			
	Erin- "I think it has to be something you just do, and then it's			
	Patty- "I feel like we haven't really done a whole lot with STEAM."			
Examining practice of STEAM	Pete-" I mean, planning would be the biggest thing, co-planning at first with someone who really knows how to do it."			
education	Erin- "It is always good to have people helping you, the right people, You know been there and done that and they know the way to do it "			
	Patty- "Probably seeing teachers do it. We need to talk to people who have done it and have had some success with it. The know- how and seeing it be done would be helpful."			
Working in a	Pete- "You know even co-teaching and breaking it down. Like I DO WE DO YOU DO kind of model "			
icar ining community	Erin- "Kind of like the time to start it, kind of like we did, and then the time to flesh it out. You would really have to keep working on it if you wanted to make it something that would full blown intertwine."			
	Patty- "My co-partner and I were planning STEM boxes for the kids. We need to get into it more. We are going to make mistakes and then change it and make it better from that. I definitely think we could make it better."			

Table 13. Thematic Coding of Interview Responses

Patty, a second-grade teacher, felt that she would be more effective at implementing STEAM integration if she could have more technology resources, particularly devices for students to use. She did not feel confident explaining STEAM to colleagues, but she thought planning time with colleagues would be a good support to "take their ideas about it" and "make it better." She would like to observe other teachers doing "a few lessons and see what materials they use." She was open to coaching based on her experiences with a mentor program during her first year of teaching.

Each teacher interviewed mentioned supports that corresponded with the themes identified by coding the open-ended portion of the post-survey responses. None of them felt particularly confident explaining STEAM integration to colleagues, which indicates that they do not wholly grasp STEAM education at the conceptual level. All participants expressed interest in observing other examples of STEAM education practice. All three participants expressed the desire for more planning and collaboration time. Another theme emerged, which was district support and the need for consistent integration of STEAM practices, with David and Erin mentioning that making STEAM integration a district focus would increase their commitment to making an effort to transform their practice. Erin felt that including STEAM activities with scaffolding in the primary grades would build students' capacity to handle self-directed tasks, which would decrease her anxiety over some managerial and implementation issues. Table 13 presents a categorization of interview text.

4.4.3 Summary

To summarize, both survey responses and interviews revealed that teachers did not gain a deep understanding of the STEAM conceptual model from the three-day summer professional learning experience. Survey responses indicate that although teachers increased their understanding of STEAM integration, they would like more information about the model. The PD experience was not enough for them to feel confident designing and implementing STEAM-integrated curriculum independently without support from more experienced teachers, support that could include watching other teachers, viewing lesson plans, or co-teaching. In addition, teachers mentioned further support through ongoing collaboration with teachers within the group, exposure to more resources for instruction, and a consistent district-wide emphasis on STEAM education.

5.0 Discussion

This section discusses key findings relating to the impact of the Teachers in the Workforce Professional Development on teachers' feelings of efficacy at developing and implementing STEAM integrated lessons in their classroom practice and how teacher lesson plans reflect STEAM teaching principles; as well as identifying additional supports teachers identify to support STEAM integration. It examines the relationship of the change to the original problem of practice, which was that students start the Junior High School STEAM rotation having had uneven experiences with technology and STEM topics. These differences exacerbate inequities associated with STEM initiatives, such as the underrepresentation of minorities and women, and the effects of the digital divide related to economic status (Dolan, 2016; Jones et al., 2018). It will evaluate the strengths and weaknesses of the change idea and explain some of the mitigating circumstances that arose during the planning and implementation of the intervention.

5.1 Mitigating Factors

Borko's (2004) framework for professional development offers a starting point to consider extenuating factors that may have impacted the findings for this research project. The framework identifies four elements that influence the impact of a professional learning experience on teacher learning. First is the **PD program**, then the **teacher participants**, the **facilitator** or presenter, and the PD **context**. It is essential to consider the ways that world events impacted each of these elements. In March of 2020, a worldwide pandemic altered many aspects of society, including schools and teaching. Due to COVID-19 restrictions, the **PD program** was a virtual experience presented through the online meeting platform Zoom. At the time, district teachers, including myself, had limited experience using online presentation modes as the school system had not mandated any synchronous instruction during pandemic-related school closures in the spring of 2020. As the sole **facilitator** of this learning experience, I was relatively new to the experience of presenting online professional development. Every attempt was made to utilize and model best practice for online instruction, including the use of social-emotional check-ins, ice breakers, polling, and break-out rooms to build collaboration (Fisher, Fry, & Hattie, 2020).

In early August 2020, the new superintendent announced that the district, with the support of the School Board, would offer only virtual instruction for the first grading period. This presented substantial professional learning challenges in the teaching **context** as the teachers struggled to contend with the shift in pedagogy, methods, materials, and assessment measures necessary for synchronous online instruction. The goals of this grant-driven PD initiative took a back seat as teacher **participants** began the process of becoming acquainted with Microsoft Teams, Clever, SeeSaw, and other digital tools. The challenges of transitioning to online teaching added to teachers' workloads and necessitated acquiring new technology skills while simultaneously transforming lesson plans and materials (LeMay, Doleck, & Bazelais, 2021).

District administrators, the Professional Development Committee, and the teachers union decided to allow teachers to use 10 hours of contracted PLC (Professional Learning Community) time before the school year started to prepare for the switch to online instruction. Per the Contracted Bargaining Agreement 2019-2023, this time was originally scheduled to include bimonthly sessions every other Wednesday during the school year, some of which was designated

to provide support for teachers in lesson planning and implementation as a part of the TIW grant. The time allocated for synchronous Wednesday PLC meetings was redistributed at will so teachers could embark on self-selected professional learning to deliver online and then hybrid instruction to students in grades K-12. This meant that teachers participating in the virtual Teachers in the Workforce Professional Development also participated in synchronous presentations by district "Techspert" or asynchronous webinars available from vendors and curriculum resources during the weeks leading up to the first day of remote learning for students on August 26th. That arrangement was extended into the second part of the school year as well, leaving no formally assigned time for the group to meet as a professional learning community. Teachers are more successful at integrating STEAM education if support is offered during the classroom implementation phase, including reflection and collaboration with peers, common planning time, and support with instructional technology (Herro, Quigley, & Cian, 2019).

5.2 Effects on Efficacy

This study investigated the effects that one nine-hour professional learning module had on teacher feelings of efficacy regarding integrating STEAM teaching activities. According to survey results and analysis of qualitative data, the biggest change was in teachers' understanding of the STEAM principles. In addition, there was a measurable shift in teachers' confidence in their ability to plan for and begin to implement STEAM integration activities in their classroom, and a greater awareness of STEAM strategies and resources. Research indicates that this does not necessarily mean that teachers will be able or willing to successfully incorporate elements of a

STEAM conceptual teaching model into their practice (Cook et al., 2020; Quigley, Herro, & Cian, 2019).

A review of the effect of STEAM integration programs in South Korea found positive effects for STEAM-related professional development, which resulted in a shift in classroom practice (Jho, Hong, & Song, 2015). However, that professional development was sustained with ongoing mechanisms for online and in-person collaboration. It is part of a nationwide focus to reform education that started in 2009 (Kim & Bolger, 2017) and is supported with funding for PD, STEAM teaching and learning material development, and an emphasis on building teacher capacity. The Jho, Hong, and Song (2016) study highlighted the important role that the teacher community had in sustaining innovations in practice necessary to support STEAM education. The researchers studied two teacher communities using both observations and interviews. They concluded that shared values and collaboration decreased anxiety about inadequate experience teaching STEAM, which would build a sense of efficacy.

This indicates that participation in a professional learning community is critical to continue to build all aspects of teacher efficacy. Nadelson et al. (2013) found positive correlations between successful STEM integration and increases in feelings of efficacy. Building teachers' confidence and feelings of efficacy about STEAM education is an important factor in building teacher capacity to implement STEAM principles successfully (Kim & Bolger, 2017). The authors found that this, in turn, had a positive effect on lesson plan development.

5.3 Lesson Plan Integration

A second question looked at the ways participants integrated elements of the conceptual model of STEAM teaching as defined by Quigley, Herro, and Jamil (2016) into the lesson plans they designed to support the TIW initiative. As a researcher utilizing improvement science methods, I identified drivers, including processes and tools, to facilitate desirable changes related to the problem of practice. One component of the PD cycle was introducing teachers to a conceptual model for STEAM integration, examining sample lessons that illustrated STEAM integration and providing them with a template that would facilitate lesson planning and encourage the application of framework elements. Huizinga et al. (2014) found that lesson planning templates, curricular frameworks, and evaluation guidelines supported teachers in the design of curriculum units, along with context-specific and integrated assistance during planning.

Artifact analysis indicated low execution rates. This is not uncommon during initial exposure to STEAM integration (Cook et al., 2020; Kang, 2019; Kim & Bolger, 2017; Quigley, Herro, & Cian, 2019). In particular, teachers struggle to integrate content from the various STEM disciplines with coherence and provide a problem scenario that encourages students to produce creative solutions to authentic tasks. Teachers indicated that planning with another teacher with content area expertise that offsets their lack of content knowledge may make transdisciplinary teaching more attainable (Quigley, Herro, & Cian, 2019). Another study by the same authors suggested a process for the design phase that includes time with a coach or colleague to develop a suitable and engaging problem that includes drafting, feedback, and revisions (Quigley et al., 2020). Bolger and Kim's study (2017) of pre-service teachers and their STEAM lesson plan development revealed links between feelings of efficacy and lesson plan progress. They found that iterative cycles of feedback provided crucial support to pre-service teachers, particularly to

ensure appropriate discipline integration and authentic task integration. TIW participants seemed to struggle with this area as well, which indicates that PD developers should offer opportunities for teachers to develop, review, revise, share, and refine lessons prior to implementation within a community of learners and with support from more experienced mentors.

5.4 Additional Supports

An important part of improvement science is gathering and analyzing data to iterate on the change idea and continue to move forward until the capacity for change is affected. Understanding that the TIW Professional Learning experience was less than ideal, a third research question looked at what supports teachers identified that would increase their ability to integrate the STEAM conceptual model. Findings indicate factors at both the individual and organizational levels.

5.4.1 Deeper Conceptualization

Participant responses indicate that they would have benefited from more information regarding the conceptual framework for STEAM education, as well as exposure to additional resources and samples. Several participants suggested that interacting with teachers who had experience enacting STEAM pedagogy would have been helpful. Shulman (1986) suggested that teacher knowledge actually should be categorized as *propositional knowledge, case knowledge,* and *strategic knowledge*. Propositional knowledge includes *principles* based on research in the field, *maxims* or practical advice often associated with or accumulated through teaching experiences, and *norms* that often reflect the teaching community's moral values. The author

pointed to *case knowledge* as a bank of "specific, well-documented, and richly described events" (p. 11) and offered that these can be in the form of prototypes or parables. He postulated that case knowledge cannot fully be absorbed without a deeper conceptual grasp and added that *strategic knowledge* is a way to understand and make professional decisions when propositional and case knowledge are incompatible. Testimonials, sample lesson plans, and videos of STEAM-based lessons were included in the professional development plan, but all activities were limited to virtual presentations. Although participants encountered sample lesson plans and Edutopia-sponsored videos of STEAM or PBL projects throughout this training module, the lack of propositional knowledge may have limited the ability to absorb case knowledge.

Hammerness et al. (2005) reminded teacher educators that sharing general strategies for teaching is ineffective without examples and models. The implications for STEAM education include a need to develop a base of case studies such as teaching videos, annotated lesson plans, and observations, along with opportunities for discussion and reflection in teacher communities. Opportunities to consider both the process and content of STEAM education can be structured to build an understanding of the foundational theories that support STEAM education and transdisciplinary teaching. Quigley and Herro (2019, p. 122) found that teachers who developed units after engaging in extensive PD to "develop a shared understanding" were less likely to struggle while planning.

5.4.2 Just in Time Feedback

Opportunities for more collaboration was a consistent theme in both interviews and survey data. Quigley and Herro (2019) identified many challenges to STEAM instruction related to the collaborative nature of planning and teaching that require an instructional shift for most teachers.

Teachers felt they had better success planning with other content teachers who had a similar understanding of the STEAM conceptual model. They found that teachers overcame barriers posed by mandated assessment policies and became comfortable building more authentic assessments and planning for formative assessment opportunities with adequate support for development and revision. This included expert and peer feedback during the curriculum design process (Quigley, Herro, & Baker, 2019).

Cook et al. (2020) performed a case study with elementary-level teams of teachers engaged in a two-year professional development experience to develop STEAM curriculum planning. The teachers met monthly as a whole group and also in building-level professional learning communities (PLCs). They found that the teachers grew in their ability to choose and align standards more meaningfully, to integrate arts and technology, and to embed formative assessments, although they continued to struggle with summative assessments that addressed multiple content areas. Developing a community of practice that includes access to both peers and STEAM practitioners with shared understanding and time for collaboration and reflection is an essential consideration for STEAM professional developers. This community of practice may even include experts outside of the teaching community if the opportunity arises (Quigley & Herro, 2019).

Cook, Bush, et al. (2020) wrote about the iterative cycle of ongoing STEAM professional development situated in the context of participants' classrooms and schools. They pointed out that when teachers act as co-constructors of the professional development experience, the process becomes cyclical. As teachers' understanding and skills build, the quality of the PD experience is enhanced. This means that teacher knowledge and skills continue to build, which will further improve the quality of the PD in a continuing process of

85

improvement. This aligns with the PDSA cycle utilized in Improvement Science models (Bryk et al., 2016), which the authors reference in their study.

5.4.3 Administrative Support

Interview transcripts yielded another theme regarding the effective enactment of STEAM practice that is referenced in the literature. Administrative or systemic commitment and support for STEAM integration are important to transform teachers' understanding and practice (Herro, Quigley, & Cian, 2019; Quigley & Herro, 2019). Grillo (2017) looked at different organizational approaches to STEAM programming and found that top-down support and emergent implementation were factors in the social construction of this relatively new approach to teaching. He defined STEAM as a socially constructed response to STEM and found that programs sometimes developed when leaders eliminate other barriers or pressures and remain present while allowing for improvisation and risk taking. Quigley and Herro (2019) acknowledged administrative support as crucial to successful STEAM implementation and categorized that support as ongoing professional development, promoting variability in assessment measures, and flexibility with scheduling to allow for greater collaboration within and beyond the teaching community. Administrative support can also mean increased technology and the ability to provide options to support all learners. The authors d that administrative support is the foundation for all other solutions to teachers' challenges when integrating STEAM instruction.

6.0 Reflection

6.1 Contextual Factors Influencing STEAM Integration

There is consensus among professional developers that teachers need to function as lifelong learners who can exhibit adaptive expertise in a world where expectations and standards for learners fluctuate and the tools for learning are rapidly changing (Hammerness et al., 2005). The past year's events have emphasized the need for teachers to transform the ways they introduce content, manage the learning environment, teach diverse learners, and assess student outcomes. However, innovation in practice requires teachers to move beyond comfortable and familiar expectations, to learn new ways of enactment, and to balance a complex set of academic and social goals for their students.

The STEAM movement is a broad educational reform effort that requires modifications in the design, tools, and practice of teaching. STEAM education has emerged from STEM education initiatives as a way for schools to equip students with knowledge in the areas of science, technology, engineering, and math while maintaining an equal focus on the development of creativity, problem-solving, and communication skills (Allina, 2018; Perignat & Katz-Buonincontro, 2019). Policymakers view STEAM education through the lens of increasing global competitiveness and economic prosperity while preparing citizens to tackle issues related to sustainability and quality of life. The integration of the Arts into STEM subjects has the added benefit of increasing student engagement and equalizing issues of misrepresentation in STEM fields (Quigley, Herro, & Jamil, 2017). However, there are discrepancies regarding the goals, vision, and methods of STEAM education that make it a challenge for teachers to understand and implement STEAM pedagogy (Perignat & Katz-Buonincontro, 2019). One way to address this is through thoughtful and effective professional learning experiences designed to clarify teachers' visions of STEAM education, their dispositions, or attitudes towards STEAM education, and their knowledge of STEAM teaching practices and tools. (Hammerness et al., 2009).

Professional development is, in itself, a complex undertaking that acts as a critical mediator in educational reform (Desimone, 2009). Therefore, it is imperative to identify salient features of effective professional development and empirical methods to evaluate the effect of teacher learning experiences. Desimone also calls for professional developers to expand their understanding of professional learning to recognize that types of professional learning can be embedded in the daily work of teaching, such as co-teaching, artifact development, and lesson reflection. Other researchers suggest that the transdisciplinary nature of STEAM education make it essential for professional learning to be situated in a community of practice (Jho, Hong, & Song, 2015). Involving teachers in curriculum design can result in substantial professional learning and increased commitment to implementation. However, teachers benefit from support during the design process as they often lack specific knowledge related to content, design, materials, and implementation strategies (Cook et al, 2020; Huizinga et al., 2014; McFadden & Roehrig, 2017, Quigley et al., 2020).

6.2 Study Limitations and Implications

This research project examined the effect that one professional learning experience had on a group of teachers in a small school district in Western Pennsylvania to build capacity to implement STEAM education models across the district. The impetus for the study was a grant from the Pennsylvania Department of Education designed to expose teachers to the skills and industry trends prevalent in the changing workforce to enhance their classroom instruction, student learning, and career readiness. Unfortunately, shutdowns and limitations due to the pandemic affected the ability to implement the grant as planned. Although online professional development can be effective, further research should assess differences between outcomes for virtual and inperson teacher learning experiences, especially in lesson plan development.

The study was restricted by several other factors as well. The lack of sustained support or opportunities to reconsider, revise, or review lesson plans as a community of practice was a significant limitation. Research indicates that curriculum design is a complex skill that requires expertise and benefits from peer input. My own professional experience supports this as I have designed both student curriculum and professional learning experiences individually and as a part of a design team. I found it more effective to do this work when there were affordances for collaboration with peers, mentors, or experts.

Being relatively inexperienced at virtual presentation, I used breakout rooms with group participants for collaborative planning opportunities. In hindsight, it would have been more effective to meet with individual teams or teachers to support them during lesson planning in order to address gaps in propositional knowledge, case knowledge, and strategic knowledge (Shulman 1986). Future research might evaluate measurable outcome discrepancies between small group or PLC based STEAM PD and larger group efforts. If STEAM education emphasizes moving away from content-centered practice to process-centered practice, it makes sense that STEAM PD should make that shift as well.

Although district literature indicates support for STEAM initiatives, no administrator participated in the Teachers in the Workforce Grant activities or professional learning experience.

89

This may have affected teachers' willingness to take risks and move outside of their customary activities, as well as the ability to make schedule changes to support teacher collaboration or shifts to the student day. There was evidence that the experience had a positive effect on teachers' feelings of efficacy, understanding, and attitudes towards STEAM education. However, the lack of top-down support for this experience most likely limited its impact. Another area for future research would be to study the effects of administrator participation in STEAM curriculum design teams.

6.3 Recommendations and Next Steps

I have the opportunity to plan future iterations of professional development related to STEAM integration. As the elementary STEAM coordinator, I have informal authority as a curriculum leader. Adaptive leadership can be both experimental and improvisational but is essentially a skill that needs to be fine-tuned through practice (Heifetz, Grashow, & Linsky, 2009). Through my coursework in this degree program based in Improvement Science, I learned to identify elements in the localized system that influence and mitigate STEAM integration. I was empowered to implement a small change intervention and collect data to measure the effects of that intervention. By connecting my data to the literature on professional learning, particularly in STEAM education and enactment initiatives, I am able to pinpoint specific changes and next steps that will sustain the original aim of this study, which was to support district teachers to develop and implement STEAM integrated units into their classroom practice. Appendix B contains a Plan-Do-Study-Act cycle that summarizes next steps for this aim. Table 14 contains specific research

questions for future consideration based on my original research questions and the results of this study.

	Table 14. Implications for Future Research				
Research Question	Results	Driving Questions for Future Research			
What do teachers report as their STEAM teaching efficacy before and after a PD intervention on STEAM integration?	Teachers did not gain a deep understanding of the STEAM conceptual model. They reported needing deeper conceptualization and ongoing collaboration.	What activities are necessary for building a deeper understanding? Are some activities (lesson study, observations) more effective than others (literature reviews and lesson plan analysis)?			
How do teachers integrate a conceptual model of STEAM teaching into their lesson planning?	Low execution rates, especially in the area of discipline integration and the development of problem scenarios.	What are the best ways to scaffold teachers as they develop each of these lesson plan characteristics? Is that scaffolding consistent at all grade levels or more dependent on the individual's teaching context and grade level?			
What do teachers identify as additional supports to enhance STEAM integration?	Teachers indicated a need for deeper conceptualization, opportunities to collaborate in a professional learning community, and administrative support.	What are ways to build the adaptive expertise of teachers in an assessment- based context? How can we teachers adapt mandated curriculum resources for STEAM instruction? What format would be best for a PLC designed to enhance and support STEAM integration? Teacher-led or expert-led? Are certain types of administrative support more effective than others (e.g., planning time and scheduling assistance or design team input?)			

Although some of these questions are beyond the sphere of a single researchers, I can take immediate steps in my own context. This will include building a repertoire of sample units and lessons that illustrate the principles of STEAM integration. The literature revealed the need to create teacher design teams (TDTs) to develop curricula and units. It would be beneficial to combine the lesson planning template and the evaluation rubric into a lesson planning checklist to guide TDTs during planning. In particular, shifting from a large group delivery mode to small group interactions may enable more personalized and targeted support for teachers in my district with the end goal of improving STEAM integration into classroom practice. Heifetz, Grashow, and Linsky (2009) suggested that adaptive leaders look backward and forward at the same time, a recommendation compatible with the Improvement Science model utilized in this study and a worthy practice for anyone wishing to create mechanisms for change.

Appendix A Document Analysis

Date of	Author/Creator	Audience	Information
Document		~ 1	
State of the	District	General	Lists STEAM curriculum and facility
District Report	Stakeholder	Public	upgrades
2019-2020	Committee		
District Reporter	Superintendent	Area citizens	Grants include:
	and staff		PA Smart and ABC Create Computer
			Science Discoveries
District	Superintendent	Potential	For the third year in a row, the
Information	and staff	residents and	elementary schools have been selected
Flyer		parents	as recipients of a STEAM (Science,
			Technology, Engineering, Art, and
			Mathematics) grant
District About	Superintendent	Parents and	Elementary STEAM Integration
Us	and staff	community	Regional STEM Partnerships
		members	
State of the	Superintendent	All	Elementary programming
District	and staff	stakeholders	 ASSET Science, Science
Fall 2019			 STEAM Integration
			•Utilize \$35,000 PA Smart Grant
			to fund/train elementary teachers
Superintendent's	Superintendent	Staff and	PA SMART Grant - STEM
Bulletin March	and staff	community	Thanks to the leadership efforts of
15, 2019		members	teacher Cathy Favo and several other
			RSD educators, RSD was selected as
			one of 16 Allegheny County education
			entities, to be awarded a \$35,000 grant
			to support professional development and
			STEM initiatives in our elementary
			schools. Job well done!
Student	Superintendent		Action Steps: Implemented Elementary
Academic	and staff		STEM program in elementary schools
Outcomes			
Report 2019			

Appendix B PDSA Cycle

	PDSAForm							
	Test Title:	Effective Professional Developmen	nt to facilitate the integration of a		l	Date: Fall 2020		
	Tester:	Catherine Favo		C	ycle#: 1 and 2			
	What Change Idea is being tested?	Professional learning intervention			C	Driver: Form and content of Professional Development		
	What is the overall goal/hypothesis	If teachers receive targeted profess	ional	development, they will be able to	deve	lop quality lesson plans that integrate STEAM pedagogy,		
	you are testing?	career and workforce emphasis an	d a 21	st Century skill focus.	_			
Η						2) DO Briefly describe what happened during the test		
Н	20 PSD teachers will participate in 0 br	wire of on line Professional Develor	ment	presented wirtually on August	-	10 teachers participated in a 0 hour professional learning		
	10 11 and 12 or August 17 19 and 10	Participants will take a pre and por	arrient at euro	presented virtually on August		averagination provided in a 9-hour professional learning		
	rolf officerov understanding of STE AM	Participants will take a pre and pos	staury	reachy standards and 21st	\sim	experience. Due to Covid 19 restrictions, the PD was		
	Century Process skills Lesson plane w	ill be used for artifact analysis to ide	methy	teady standards and 2 ist	►⁄	ekills stylepts peed to success in the changing workplace		
	intervention interviews of a focus group	(n=5) will be analyzed and coded to	a iden	tify additional supports or issues		and how to structure classroom, activities to foster the		
	that arise during lesson implementation	(II-5) Will be analyzed and coded to	Juch	iny additional supports or issues		development of those skills. They had fine to examine the		
	that alloe during resourt implementation	L				PA Career standards and resources available of teachers on		
	•					the PA Career Stadnadirds website. Then participants learned		
						achut the elements of a STEAM concentral model to guide		
						them as they collaborated on lesson plans to include these		
Н	Questione: Questions you have shout	Desdiction of Make a productor	Data	Data you'll collect to test		What were your resulte? Comment on your and infere in		
	Questions: Questions you have about	Predictions: Make a prediction	Data	: Data you'll collect to test	L	What were your results / Comment on your predictions in		
	what will happen. What do you want to	for each question. Not optional.	predictions.		L	the box below. Were they correct? Record any data		
Н	learn?	Teachers will separt increased	Dec.	and Doot Survey Leases also	<u> </u>	summanes as well.		
	what do leachers in my district report	officeous The ingreece in officeous	PTE a	ata interviewa	L.	A null hypothesis would assume that there would be no		
	before and after a professional	will differ according to content	arua	cis, interviews	$ \rightarrow $	intensiew recomments. Analysis of pre- and post-survey		
	development internetion on STEAM	area, teaching context				responses, indicates that the participants reported ingreases		
Н	In what wave do teachers integrate a	Teachers will integrate some		on plan artifacte Poet	<u>├</u>	Statistical analysis showed that teachers were fairly		
	concentual model of STEAM teaching	elements of the concentral model	inten	ention interviews		successful at integrating technology and career standards into		
	practices as defined by Quidley Herro	but not all An analysis of which			$ \rightarrow $	their lesson plans, but less successful at discipline integration		
	& lamil (2017) into their lesson plans?	elements were included and which				and offering students choice over process or assessment		
		were not will be useful to guide				products, community issues or create opportunities for		
		other interventions.				students to apply content knowledge to real-world tasks.		
Η	What do teachers in my district identify	Teachers will identify additional	Open	ended survey data, Post	5	Survey and interviews revealed that teachers wanted more		
	as additional supports that will assist	supports that are consistent within	inter	vention interviews		information about the STEAM conceptual model, more		
	them in implementing these lesson	research literature: Instructional				examples and testimonials from experienced teachers along		
	plans?	time, administrative support,				with time to collaborate and plan with peers.		
Π					P	1 1		
	4) ACT Describe modifications and/or d	lecisions for the next cycle; what		3) STUDY What did you learn?				
	This PD module should be modified to i	include more expert support of		I learned that this experience did not provide enough support for successful enactment and				
	teacher design teams, as well as more	testimonials, examples, and lesson		implementation of the STEAM c	oncept	tual model. Teachers need greater conceptualization of the		
	videos. The next cycle should include a	ffordances for ongoing support	~	STEAM model, on-going and su	staine	d support from peers and experts relevant to the problem		
	during lesson plan development, impler	mentation, and revisions based on	d on space students will expore. In addition, administrative support would release teachers from the weight of demands such as scheduling, pacing, and the emphasis on high stakes testing result					
	reflection.							
				impede their willingness or abilting	y to integrate STEAM education practices.			

Appendix C Professional Development Agendas

Day 1

Goals:

1. Consider what is meant by the term 21st century skills

2. Set goals for our teaching to incorporate or develop 21st century skills

3. Explore PA Career Standards at participants' grade level

Buncee presentation board:

https://app.edu.buncee.com/buncee/b460780a053a474c957f5ef200828d2c

DRIVING QUESTION: What is the purpose of education?

- A. Pre-Survey and opener. Participants were given time to take a survey and then asked to find three specific items to share with a small group
 - 1. Ice breaker: Share items in breakout rooms

2. Discussion: Share takeaways from the site visits to various workplaces and comment using a tool called Padlet

- B. 21st Century Skills
 - 1. 3 videos on 21st Century skills
 - 2. Pass the Ball game to share one word related to 21st Century skills
 - 3. Read and annotate article Future Work Skills- share thoughts in small groups

SR-1382A UPRI future work skills sm.pdf

- C. PA Career Readiness Skills-
 - 1. State requirements/RSD requirements
 - 2. Discussion of artifacts and eyeball yoga break

3. Exploration of PA standards and other resources in TEAMS <u>Career Continuum per Band and pamphlet.pdf</u>

- D. Preparing for tomorrow:
 - 1. Project-based learning video
 - 2. STEAM project video
 - 3. Time to develop or brainstorm lesson planning ideas

Day 2

Goals:

Become familiar with the Teachers in the Workforce Grant requirements

Learn about two instructional models: Project-Based Learning and a STEAM Conceptual Model

Evaluate two lessons that follow each model

Come up with an idea for your own lesson

Buncee presentation board: https://app.edu.buncee.com/buncee/16e11ced263e4e37a341c3859eadc835

DRIVING QUESTION: What are some core practices that support the development of key competencies for students today?

- A. Review of grant expectations: Lesson plan development and artifact collection
- B. Review elements of a Project Based Learning (PBL) Model Lesson -
 - 1. Career and Academic Standard Integration
 - 2. Authentic Audience
 - 3. Student Choice
 - 4. Authentic/Formative assessment.
- C. PBL lesson study
1. Analyze a project-based lesson plan for those elements

- 2. PBL lesson discussion
- D. Brain Break- Disruptus Game to stimulate creativity-

E. Introduce STEAM Conceptual Model

Problem-	Integration	Career	21 st	Technology	Authentic	Student
Based		Skills	Century Skills	Integration	Tasks	Choice

- 1. Problem scenario
- 2. Transdisciplinary content grounded in the problem
- 3. Career exposure/ skills
- 4. 21st century skill development
- 5. Technology integration
- 6. Authentic tasks
- 7. Student choice

F. STEAM Lesson Study:

- 1. Analyze a lesson plan for these elements in small groups
- 2. STEAM lesson plan discussion
- G. Share ideas for possible lesson plans

Day 3

Goals:

Develop skills as a 21st century teacher

Begin/finish a lesson plan that incorporates some of the elements that we discussed in this

PD

Have opportunities for support, collaboration, and sharing

Buncee presentation board: <u>https://app.edu.buncee.com/buncee/16e11ced263e4e37a341c3859eadc835</u>

DRIVING QUESTION: How can we plan classroom activities to build 21st century process skills and support STEAM integration??

- A. Ice Breaker and opener
 - 1. Fun activities: Virtual Wave and Goats in the Grass
 - 2. Edutopia Article "15 Characteristics of a 21st century teacher discussion
- B. Collaborative lesson planning in grade-level groups using breakout rooms
- C. Group Share and post-survey

Appendix D Teachers in the Workforce PD Pre-survey

Start of Block: Introduction

O27 The purpose of this research study is to assess the effects of a targeted professional development experience on teachers' feelings of efficacy and lesson plan development. All School District. I will be asking participants to participants must be teachers in the complete a brief questionnaire before and after a Professional Learning experience. If you are willing to participate, this brief (15 minute) survey will ask about your teaching experience, knowledge of and feelings about STEAM pedagogy, Career Readiness Standards and your familiarity with 21st Century skills. The lesson plans developed as a part of this professional learning experience will be analyzed using a device designed by the Principal Investigator of this Some of you may also be asked to volunteer to participate in a semi-structured study. interview. The interview will consist of approximately 7 questions and will take less than 1 hour. Your responses will be recorded but will be stored, coded and reported using pseudonyms. All responses will be confidential, and the results will be kept in password protected files on private devices that are the personal property of the Principal Investigator. There are no foreseeable risks associated with this project other than the risk of breach of confidentiality, nor are there any direct benefits to you. You will not be compensated for participating in the interview process. Administrators of the second School District will not have access to any data and will not know who participated in the study. Your participation is voluntary, and you may stop completing the survey, withdraw your lesson plan or end the interview at any time. Please click 'next' if you are

willing to participate. This study is being conducted by the Principal Investigator Catherine Favo,

who can be contacted a pitt.edu or 4

Next (please press the arrow to continue)

End of Block: Introduction

Start of Block: Conceptual understanding

Q13 What is your name?

Q14 How would you define the practice of STEM education?

Q15 How would you define the practice of STEAM education?

End of Block: Conceptual understanding

Start of Block: Demographics- please answer these questions about your teaching experience.

Q1 How long have you been teaching in a k-12 setting?

- 0-5 years (1)
- \bigcirc 6-10 years (2)
- \bigcirc 11-15 years (3)
- ○16-20 years (4)
- \bigcirc 20 plus years (5)

Q2 What is your educational background? Please check all that apply.

\Box 4 year degree in education field (1)
4 year degree in content (non-education) related field (2)
Master's degree in education field (3)
Coursework for additional certification (4)
Post Master's level graduate work (5)

Q3 What professional development experiences have you had that covered STEAM pedagogy or instruction?

 \bigcirc None at all (1)

 \bigcirc A little (2)

 \bigcirc A moderate amount (3)

 \bigcirc A lot (4)

 \bigcirc A great deal (5)

Q5 What grade level(s) do you teach?

Please check all that apply.



Q6 What content areas do you teach? Please check all that apply.



End of Block: Demographics- please answer these questions about your teaching experience.

Start of Block: STEAM understanding and efficacy

Q9 This section is designed to help me learn about teacher understanding and confidence related to STEAM teaching and learning.

	Not at all (1)	A little (2)	A moderate amount (3)	A lot (4)	A great deal (5)
I understand what integrated STEAM teaching means. (1)	0	0	0	0	0
I am comfortable planning integrated STEAM activities for my students. (2)	0	\bigcirc	\bigcirc	\bigcirc	0
I am comfortable implementing integrated STEAM activities with my students. (3)	0	\bigcirc	\bigcirc	0	0
I believe that including STEAM integration within my curriculum is valuable for students. (4)	0	\bigcirc	\bigcirc	\bigcirc	\bigcirc
I believe that incorporating STEAM integration in my curriculum is within my reach currently. (5)	0	0	\bigcirc	\bigcirc	\bigcirc

I am knowledgeable about strategies and resources for STEAM integration. (6)	0	\bigcirc	\bigcirc	0	0
I would need additional support to incorporate STEAM integration into my classroom curriculum. (7)	0	\bigcirc	\bigcirc	\bigcirc	0

End of Block: STEAM understanding and efficacy

Start of Block: Career Readiness and Preparation

Q10 This section is to help me learn about teachers' attitudes towards and familiarity with the PA Career Readiness Standards.

	Not at all (1)	A little (2)	A moderate amount (3)	A lot (4)	A great deal (5)
I am knowledgeable about the PA Career Readiness Standards. (1)	0	0	0	0	0
I believe that it is important for students to have experiences that build understanding of different careers and builds readiness for entry into the workforce. (2)	0	0	0	\bigcirc	\bigcirc
I am confident planning activities that enhance understanding of different careers and builds readiness for entry into the workforce. (3)	0	0	0	\bigcirc	0
I am confident implementing activities that enhance understanding of different careers builds readiness for entry into the workforce. (4)	0	0	\bigcirc	0	\bigcirc

I would need additional support to incorporate career understanding and readiness skills into my classroom Curriculum. (5)	0	0	0	\bigcirc	0
--	---	---	---	------------	---

End of Block: Career Readiness and Preparation

Start of Block: 21st Century Skills

Q11 This section is to help me learn about teachers understanding of and attitudes towards 21st Century skill integration. For clarity, 21st Century skills are skills deemed essential to participate meaningfully in the workforce of the future (creativity, innovation, problem solving, collaboration, critical thinking, communication).

	Not at all (1)	A little (2)	A moderate amount (3)	A lot (4)	A great deal (5)	
I understand what skills are important to succeed in the workforce today and in the future. (1)	0	0	0	0	0	
I believe that it is important to include activities in the classroom that develop 21st Century skills. (2)	0	0	0	\bigcirc	0	
I am confident in my ability to plan activities in the classroom that develop 21st Century skills. (3)	0	0	0	0	0	
I would need additional support to incorporate activities that develop 21st Century skills into my classroom Curriculum. (4)	0	0	0	0	0	
End of Block: 21st Century Skills						

110

Appendix E Teachers in the Workforce PD Post-survey

Start of Block: Introduction

Q13 The purpose of this research study is to assess the effects of a targeted professional development experience on teachers' feelings of efficacy and lesson plan development. All participants must be teachers in the **Excercise** School District.

I will be asking participants to complete a brief questionnaire before and after a Professional Learning experience. If you are willing to participate, this brief (15 minute) survey will ask about your teaching experience, knowledge of and feelings about STEAM pedagogy, Career Readiness Standards and your familiarity with 21st Century skills. The lesson plans developed as a part of this professional learning experience will be analyzed using a device designed by the Principal Investigator of this study. Some of you may also be asked to volunteer to participate in a semi-structured interview. The interview will consist of approximately 7 questions and will take less than 1 hour.

Your responses will be recorded but will be stored, coded and reported using pseudonyms. All responses will be confidential, and the results will be kept in password protected files on private devices that are the personal property of the Principal Investigator.

There are no foreseeable risks associated with this project other than the risk of breach of confidentiality, nor are there any direct benefits to you. You will not be compensated for participating in the interview process.

Administrators of the **School** District will not have access to any data and will not know who participated in the study. Your participation is voluntary, and you may stop completing the survey, withdraw your lesson plan or end the interview at any time. Please click 'next' if you are willing to participate.

This study is being conducted by the Principal Investigator Catherine Favo, who can be contacted at at a pitted or at a state of the st

Next (please press the arrow to continue)

Q30 Please record your name below.

Q31 I have read the script above.

 \bigcirc yes (1)

Ono (2)

End of Block: Introduction

Start of Block: Demographics- please answer these questions about your teaching experience.

Q2 How long have you been teaching in a k-12 setting?

0-5 years (1)
6-10 years (2)
11-15 years (3)
16-20 years (4)
20 plus years (5)

Q3 What is your educational background? Please check all that apply.

4 year degree in education field (1)
4 year degree in content (non-education) related field (2)
Master's degree in education field (3)
Coursework for additional certification (4)
Post Master's level graduate work (5)

Q4 What professional development experiences have you had that covered STEAM pedagogy or instruction?

(For clarity, we will define STEAM as a transdisciplinary method of teaching that addresses real life situations and problems while integrating components of science, technology, engineering, the arts, and math content.)

None at all (1)
A little (2)
A moderate amount (3)
A lot (4)
A great deal (5)

Q5 What grade level(s) do you teach?

Please check all that apply.



Q6 What content areas do you teach? Please check all that apply.



End of Block: Demographics- please answer these questions about your teaching experience.

Start of Block: STEAM understanding and efficacy

Q7 This section is designed to help me learn about how teacher understanding and confidence related to STEAM teaching and learning grew or changed as a result of this professional learning experience.

	Not at all (1)	A little (2)	A moderate amount (3)	A lot (4)	A great deal (5)
I understand what integrated STEAM teaching means. (1)	0	0	\bigcirc	0	0
I am comfortable planning integrated STEAM activities for my students. (2)	0	0	0	\bigcirc	\bigcirc
I am comfortable implementing integrated STEAM activities with my students. (3)	0	0	\bigcirc	0	\bigcirc
I believe that including STEAM integration within my curriculum is valuable for students. (4)	0	0	\bigcirc	0	\bigcirc
I believe that incorporating STEAM integration in my curriculum is within my reach currently. (5)	0	0	\bigcirc	\bigcirc	\bigcirc

I am knowledgeable about strategies and resources for STEAM integration. (6)	0	0	0	0	\bigcirc
I would need additional support to incorporate STEAM integration into my classroom curriculum. (7)	0	\bigcirc	\bigcirc	\bigcirc	\bigcirc

Q8 What other supports beyond this professional learning experience might help you incorporate STEAM integration?

Q32 How does STEAM education differ from STEM education?

End of Block: STEAM understanding and efficacy

Start of Block: Career Readiness and Preparation

Q9 This section is to help me learn about teachers' attitudes towards and familiarity with the PA Career Readiness Standards grew or changed as a result of this professional learning experience.

	Not at all (1)	A little (2)	A moderate amount (3)	A lot (4)	A great deal (5)
I am knowledgeable about the PA Career Readiness Standards. (1)	0	0	0	0	0
I believe that it is important for students to have experiences that build understanding of different careers and builds readiness for entry into the workforce. (2)	0	0	0	\bigcirc	\bigcirc
I am confident planning activities that enhance understanding of different careers and builds readiness for entry into the workforce. (3)	0	\bigcirc	\bigcirc	\bigcirc	0
I am confident implementing activities that enhance understanding of different careers builds readiness for entry into the workforce. (4)	0	\bigcirc	0	\bigcirc	\bigcirc

I would need additional support to incorporate career understanding and readiness skills into my classroom Curriculum. (5)	\bigcirc	\bigcirc	0	0	0
--	------------	------------	---	---	---

End of Block: Career Readiness and Preparation

Start of Block: 21st Century Skills

	Not at all (1)	A little (2)	A moderate amount (3)	A lot (4)	A great deal (5)
I understand what skills are important to succeed in the workforce today and in the future. (1)	0	0	\bigcirc	0	0
I believe that it is important to include activities in the classroom that develop 21st Century skills. (2)	0	\bigcirc	\bigcirc	\bigcirc	\bigcirc
I am confident in my ability to plan activities in the classroom that develop 21st Century skills. (3)	0	\bigcirc	\bigcirc	\bigcirc	\bigcirc
I would need additional support to incorporate activities that develop 21st Century skills into my classroom Curriculum. (4)	0	\bigcirc	\bigcirc	0	0

Q11 This section is to help me learn about teachers' understanding of and attitudes towards 21st Century skill integration grew or changed as a result of this professional learning experience.

End of Block: 21st Century Skills

Appendix F STEAM DESIGN Unit Plan Rubric

This is the link to the Lesson Plan Rubric for artifact analysis.

https://pitt.co1.qualtrics.com/Q/EditSection/Blocks?SurveyID=SV_eOQiT3q8T2butX8

Name and content area or grade level targeted.

Problem Based

- \circ Lesson does not present students with a problem to solve or a problem scenario. (1)
- Lesson provides problem-based learning; however, the problem is not relevant to students' lives or require them to offer solutions. (2)
- Lesson provides a problem that has some relevance to students' lives, interests, or community, but plan does not call for students to investigate to form solutions to the problem. (3)
- Lesson is based on a problem that is globally, geographically, or locally relevant and has the capacity to engage students in forming solutions to the problem. (4)

Discipline integration

- \circ Lesson calls for knowledge or resources from a single content area. (1)
- Lesson makes an attempt to connect with resources, content, or experts from another STEAM discipline. (2)
- Lesson incorporates other disciplines across some STEAM content areas. (3)
- The lesson offers opportunities to encounter and use knowledge or skills from multiple STEAM content areas. (4)

Career Standards integration

- Lesson plan does not connect to any STEM related job or career skill. (1)
- Lesson connects to basic career skills like organization and time management, but not specifically STEM career skills. (2)
- Lesson provides opportunities for students to explore STEM careers or utilize STEM career skills. (3)
- Lesson provides opportunities to connect to STEM careers and skills as applied to realistic tasks or to solve problems. (4)

21st-century skill development

- Lesson plan does not offer students opportunities to practice skills such as collaboration, critical thinking, creativity, and a variety of communication skills. (1)
- Lesson plan offers limited opportunities to practice skills such as collaboration, critical thinking, creativity, and a variety of communication skills. (2)
- Lesson plan offers multiple opportunities to practice skills such as collaboration, critical thinking, creativity, and a variety of communication skills. (3)
- Lesson plan offers multiple opportunities to practice skills such as collaboration, critical thinking, creativity, and a variety of communication skills to address the problem or problem scenario. (4)

Technology Integration

- \circ The teacher does not integrate technology. (1)
- The teachers integrate technology as an instructional tool. (2)
- The teacher integrates appropriate technology as an instructional tool and as a way for students to respond or communicate. (3)
- The teacher integrates appropriate technology as a means of learning, communicating and/or presenting creative solutions to problem or problem scenario. (4)

Authentic tasks

- The tasks required are not relevant to students' lives, their interests or their cultural, geographical, global, or local community. (1)
- The tasks have limited relevance to students' lives, their interests, or their cultural, geographical, global, or local community. (2)
- The tasks have some connection to students' lives, their interests or their cultural, geographical, global, or local community. (3)
- The tasks are designed to address problems or problem scenarios that are connected to students' lives, their interests or their cultural, geographical, global, or local community. (4)

Student Choice

- Students do not have choices in either the process of learning, method of inquiry, or product/assessment tool. (1)
- Students have limited choices in either the process of learning, method of inquiry, or product/assessment tool. (2)
- Students have opportunities to choose the process of learning, method of inquiry, and/or product/assessment tool. (3)
- Students have opportunities to direct their own learning and have choice over process and product as a means for problem solving or to approach a problem scenario. (4)
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Appendix G STEAM DESIGN Analysis and Descriptors

Grade Level/Topic	Problem- Based	Integration	Career Skills	21 st Century Skills	Technology Integration	Authentic Tasks	Student Choice
7th grade team- Candy Analysis and Creation	Lesson provides problem-based learning; however, the problem is not relevant to students' lives or require them to offer solutions.	Lesson incorporates other disciplines across some STEAM content areas.	Lesson provides opportunities for students to explore STEM careers or utilize STEM career skills.	Lesson plan offers limited opportunities to practice skills such as collaboration, critical thinking, creativity and a variety of communication skills.	The teacher integrates appropriate technology as an instructional tool and as a way for students to respond or communicate.	The tasks have limited relevance to students' lives, their interests or their cultural, geographical, global or local community.	Students have limited choices in either the process of learning, method of inquiry or product/assessment tool.
Kindergarten -Bird and animal homes	Lesson provides a problem that has some relevance to students' lives, interests or community, but plan does not call for students to investigate to form solutions to the problem.	Lesson makes an attempt to connect with resources, content or experts from another STEAM discipline.	Lesson provides opportunities for students to explore STEM careers or utilize STEM career skills.	Lesson plan offers limited opportunities to practice skills such as collaboration, critical thinking, creativity and a variety of communication skills.	The teacher integrates appropriate technology as an instructional tool and as a way for students to respond or communicate.	The tasks have limited relevance to students' lives, their interests or their cultural, geographical, global or local community.	Students have limited choices in either the process of learning, method of inquiry or product/assessment tool.

2nd Grade Community Flooding Solutions	Lesson is based on a problem that is globally, geographically or locally relevant and has the capacity to engage students in forming solutions to the problem.	Lesson incorporates other disciplines across some STEAM content areas.	Lesson provides opportunities to connect to STEM careers and skills as applied to realistic tasks or to solve problems.	Lesson plan offers limited opportunities to practice skills such as collaboration, critical thinking, creativity and a variety of communication skills.	The teacher integrates appropriate technology as an instructional tool and as a way for students to respond or communicate.	The tasks are designed to address problems or problem scenarios that are connected to students' lives, their interests or their cultural, geographical, global or local community.	Students have opportunities to choose the process of learning, method of inquiry and/or product/assessment tool.
9th Grade English: Career Cluster Investigation	Lesson provides a problem that has some relevance to students' lives, interests or community, but plan does not call for students to investigate to form solutions to the problem.	Lesson calls for knowledge or resources from a single content area.	Lesson connects to basic career skills like organization and time management, but not specifically STEM career skills.	Lesson plan offers limited opportunities to practice skills such as collaboration, critical thinking, creativity and a variety of communication skills.	The teacher integrates appropriate technology as an instructional tool and as a way for students to respond or communicate.	The tasks have some connection to students' lives, their interests or their cultural, geographical, global or local community.	Students have limited choices in either the process of learning, method of inquiry or product/assessment tool.
11th Grade Career Shadow	Lesson provides a problem that has some relevance to students' lives, interests or community, but plan does	Lesson makes an attempt to connect with resources, content or experts from	Lesson provides opportunities for students to explore STEM careers or utilize	Lesson plan offers limited opportunities to practice skills such as collaboration, critical thinking, creativity and a	The teacher integrates appropriate technology as an instructional tool and as a way for students to	The tasks have some connection to students' lives, their interests or their cultural, geographical, global or	Students have limited choices in either the process of learning, method of inquiry or product/assessment tool.

	not call for students to investigate to form solutions to the problem.	another STEAM discipline.	STEM career skills.	variety of communication skills.	respond or communicate.	local community.	
Gifted Ed. Career Portfolio	Lesson does not present students with a problem to solve or a problem scenario.	Lesson makes an attempt to connect with resources, content or experts from another STEAM discipline.	Lesson provides opportunities for students to explore STEM careers or utilize STEM career skills.	Lesson plan offers limited opportunities to practice skills such as collaboration, critical thinking, creativity and a variety of communication skills.	The teacher integrates appropriate technology as an instructional tool and as a way for students to respond or communicate.	The tasks have some connection to students' lives, their interests or their cultural, geographical, global or local community.	Students have limited choices in either the process of learning, method of inquiry or product/ assessment tool.
Special Ed and grade 1 Light and Sound Device Challenge	Lesson is based on a problem that is globally, geographically or locally relevant and has the capacity to engage students in forming solutions to the problem.	Lesson incorporates other disciplines across some STEAM content areas.	Lesson provides opportunities for students to explore STEM careers or utilize STEM career skills.	Lesson plan offers multiple opportunities to practice skills such as collaboration, critical thinking, creativity and a variety of communication skills to address the problem or problem	The teacher integrates appropriate technology as an instructional tool and as a way for students to respond or communicate.	The tasks have some connection to students' lives, their interests or their cultural, geographical, global or local community.	Students have opportunities to choose the process of learning, method of inquiry and/or product/ assessment tool.
9-12 Foods Planner Use	Lesson does not present students with a problem to solve or a	Lesson calls for knowledge or resources from a single	Lesson connects to basic career skills like organization and time	Lesson plan offers limited opportunities to practice skills such as collaboration,	The teacher integrates appropriate technology as an instructional tool and as a	The tasks have some connection to students' lives, their interests or	Students do not have choices in either the process of learning, method of inquiry or product/

	problem scenario.	content area.	management, but not specifically STEM career skills.	critical thinking, creativity and a variety of communication skills.	way for students to respond or communicate.	their cultural, geographical, global or local community.	assessment tool.
9-12 Special Ed Maintaining Biodiversity	Lesson is based on a problem that is globally, geographically or locally relevant and has the capacity to engage students in forming solutions to the problem.	Lesson makes an attempt to connect with resources, content or experts from another STEAM discipline.	Lesson provides opportunities to connect to STEM careers and skills as applied to realistic tasks or to solve problems.	Lesson plan offers multiple opportunities to practice skills such as collaboration, critical thinking, creativity and a variety of communication skills to address the problem or problem scenario.	The teacher integrates appropriate technology as a means of learning, communicating and/or presenting creative solutions to problem or problem scenario.	The tasks have some connection to students' lives, their interests or their cultural, geographical, global or local community.	Students have opportunities to choose the process of learning, method of inquiry and/or product/ assessment tool.

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