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# An Asset-based Approach to Problem-based Learning in K-12 STEM

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# AN ASSET-BASED APPROACH TO PROBLEM-BASED LEARNING IN K-12 STEM

by

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# ABSTRACT

Educators and policymakers advocate for the implementation of problem-based approaches to STEM education in K-12 classrooms to help students develop 21st-century skills such as the ability to think critically, collaborate, and problem-solve. The first exploratory case study in this three-article dissertation examines how students engage in STEM-focused PBL experiences and the meaning of these experiences for the development of their STEM identities. The second study utilizes Braun and Clarke's reflective thematic analysis framework to explore the experience of a model STEM teacher at a high-performing STEM-focused elementary school as she implemented problem-based learning in the first year of a school-wide progressive reform initiative. Overall findings from the first two articles indicated missed opportunities to connect students' lived experiences to the problem-solving process. The final article in this study introduces the practice of asset mapping, which has traditionally been used in the field of social work and community development and applies it to the context of a STEM-focused PBL activity. The novel *Problem-based Learning through Asset Mapping (PLAM) Framework* recognizes the assets students bring to the learning process and supports educators aiming to leverage these assets to solve problems that are relevant and meaningful to learners.

I dedicate this dissertation to my husband Greivin and my two boys, Ian and Miles, who have supported and believed in me throughout this journey. This work is also dedicated to the students who have taught me more about strength, resilience, and bravery then they will ever know. Finally, I dedicate this research to the incredible educators who inspire me every day.

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# CHAPTER ONE: INTRODUCTION

In the United States, women account for over 60% of college graduates; however, only 20% of people earning degrees in computer science and engineering are women. The outlook is even more troubling for African American and Hispanic women looking to enter the workforce in these fields, as they comprise fewer than 6% of employed scientists and engineers (National Science Foundation, 2019). Prior research has shown that the unbalanced representation of women with careers in science, technology, engineering, and mathematics (STEM) fields is not the result of a lack of ability, as standardized tests indicate no difference in scores between boys and girls in math or science during the early stages of their academic careers (National Science Foundation, 2019). One explanation for the disparity in workforce participation is an incongruence between the culture of STEM education and the ways that women perceive themselves as scientists, technologists, engineers, and mathematicians in STEM settings (Kourany, 2002; Soylu Yalcinkaya & Adams, 2020). It is important to consider self-perceptions as young girls are first introduced to the sociocultural context of science in school classrooms.

Experiences in traditional science classrooms shape students' understanding of what constitutes scientific knowledge, who produces it, how it is used, and what role they play in the process (Driver et al., 1994). Research in science education for underrepresented youth has found that developing a strong science identity promotes students' persistence in STEM, improves academic performance, and increases the number of students who complete degrees in STEM-related fields (Atkins et al., 2020; Chang et al., 2014; Maton et al., 2016). Problem-based STEM experiences grounded in constructivist learning principles are a tool for educators to engage and motivate learners. A problem-based learning approach to STEM education may provide educators the opportunity to capitalize on factors known to contribute to students' positive self-efficacy beliefs (Chis et al., 2018; Margot & Kettler, 2019). These beliefs are an essential component of the STEM-identity process.

Strengthening the STEM identities of underrepresented groups remains critical to address the lack of STEM-related workforce participation of minority groups. Prior research has demonstrated the significance of pedagogical choices and teacher interactions in the development of students' STEM identity, especially related to minority girls (Brickhouse et al., 2000; Carlone et al., 2014; Merolla et al., 2012; Strong, 2016). Educators and policymakers advocate for the implementation of PBL in K-12 classrooms to help students to develop 21st-century skills such as the ability to think critically, collaborate, and problem-solve (Edmunds et al., 2017; Partnership for 21st Century Learning, 2019).

Lack of access to STEM-based learning experiences in K-12 environments is one of many possible factors contributing to the gap in STEM achievement that persists for minority students attending low-income schools (Barton et al., 2016). Research examining how formal science classroom environments are perceived by underrepresented students may provide educators insights into how best to strengthen STEM identities for students. The purpose of *Article One* of this dissertation explores STEM-focused problem-based learning (PBL) as a strategy to strengthen the STEM identity of underrepresented youth, specifically for minority girls who are least likely to view themselves in a STEM role.

A problem-based approach to STEM instruction that includes aspects of design and making has been recognized as a gateway to STEM education for traditionally underrepresented students (Sheridan et al., 2014). Research suggests that these types of learning experiences contribute to increased content knowledge (Shulman, 2013), student engagement (Bevan et al., 2015; Kuh, 2008), and motivation for STEM learning (Hand, et al., 2003). Others have purported that design and making could potentially contribute to career interest in STEM-related fields as they are often STEM-based learning activities (Diaz & King, 2007).

Educators are an essential component in the implementation of STEM-focused PBL. They determine if and how constructivist epistemology will be used in the context of their science classrooms (Beck et al., 2000; Luehmann, 2007). Self-efficacy beliefs have been shown to positively contribute to teachers' motivation to implement innovative instructional practices. These practices require teachers to extend the same persistence, effort, and resilience expected from their students participating in PBL (Blumenfeld et al., 1991; Pajares, 1996; Ravitz, 2010). Examining teacher self-efficacy in task-specific STEM-focused environments may help researchers more accurately predict teachers' motivation to apply a PBL approach to teaching STEM content (Bandura, 1995; Pajares,1996). *Article Two* of this dissertation shifts focus from student science identity to examine factors related to the implementation of PBL by a model educator at a STEM-focused elementary school.

Learners in K-12 settings across the country bring to the classroom a wide array of educational experiences, cultural practices, and individual identities. As an instructional practice, problem-based learning (PBL) views students' prior knowledge and lived experiences as valuable tools that can be utilized to solve problems that are both meaningful and relevant to their lives (Hung, 2011; Savery, 2015). Providing opportunities for learners to build upon prior knowledge can serve to validate their experiences and help develop and strengthen their identities as valued participants in the larger learning community (Darder, 2012; López, 2017). Further, an asset-based approach to PBL instruction may encourage learners to recognize their prior knowledge and skills and discover ways to leverage their word views, cultural perspectives, and lived experiences throughout the learning process. *Article Three* of this dissertation introduces a PBL-focused asset mapping tool for educators that prompts students to consider various ways in which experiences from their everyday lives can be used as resources in the context of problem-solving. Implementing this asset mapping activity prior to participation in a PBL challenge can also assist educators as they work to develop an awareness of the social, cultural, and digital assets students already possess and that can be utilized in the learning process.

## Purpose of the Study

Educators and policymakers advocate for the implementation of problem-based approaches to STEM education in K-12 classrooms to help students develop 21st-century skills such as the ability to think critically, collaborate, and problem-solve (Edmunds et al., 2017; Partnership for 21st Century Skils, 2019). Lack of access to quality STEM-based learning experiences in K-12 environments is one of many possible factors contributing to the gap in STEM achievement that persist for minority students attending low-income schools (Barton et al., 2017).

Adolescence has been described by researchers as a critical stage in students' academic trajectories with implications for future aspirations to enroll in STEM-related courses (Carlone et al., 2014). Research that provides instructional tools that can support educators implementing STEM-focused PBL experiences in formal learning environments has the potential to strengthen students' STEM identity development, particularly for those interested in pursuing careers where they are often underrepresented (Coleman & Davis, 2020).

The purpose of *Article One* is to describe the experiences of two African American girls as they participate in STEM-focused PBL within the context of a school science classroom and the meaning of these experiences for their STEM identities. Insight from the data collected in this study may help instructional designers and practitioners better design and implement STEM-based active learning problems that promote STEM-identity formation for traditionally underserved and underrepresented groups.

The purpose of *Article Two* is to describe the experience of a model teacher at a high-performing STEM-focused elementary school as she implements PBL in the first year of a school-wide progressive reform initiative. Findings from this study provide classroom teachers, administrators, district leaders, and state policymakers with insight into how school culture can be leveraged to support teachers as they implement PBL. Findings can provide guidance to administrators tasked with choosing model teachers and school leaders to support and promote a PBL reform effort that is practical, productive, and sustainable.

The purpose of *Article Three* is to discuss the impact of asset-based approaches to STEM-focused PBL and provide educators with a tool that prompts students to consider various ways that experiences from their everyday lives can be used as resources in the context of problem-solving. Findings highlight the potential of asset mapping to engage and motivate students in STEM-focused PBL settings as well as provide instructional designers and practitioners insight into best practices and tools to resist a deficit-based narrative and actively work to reframe their own perspectives.

## Theoretical Frameworks

The theoretical frameworks for the qualitative research in this dissertation include two theoretical lenses. In *Article One*, Carlone and Johnson's (2007) science identity model views the development of science identity as intersectional and context dependent. In this view, developing science identity occurs gradually over time, considers individual traits such as race, gender, and ethnicity, and includes three interrelated dimensions: *competence*, *performance*, and *recognition* (Carlone & Johnson, 2007). The science identity framework was adopted as a flexible lens for data interpretation for *Article One* as initial coding revealed multiple instances of words associated with the framework's three dimensions of science identity. Lave and Wegner's (1991) situated learning framework was also utilized to address findings by examining the relationship between girls' narrated and embodied identities-in-practice.

In *Article Two*, teacher efficacy and epistemic beliefs, and attitudes about teaching and learning are often expressed through the enactment of instruction (Pajares, 1992; Peterman, 1993; Tobin, 1993). Problem-based learning (PBL), an instructional strategy guided by inquiry-based learning, is supported by variations of the constructivist theoretical framework (Bell, 2010). As the constructivist epistemology is widely viewed as the foundation of an ideal PBL environment, it will serve as the theoretical lens for examining teacher beliefs and experiences implementing STEM-focused PBL in the classroom (Pecore, 2012). In addition, self-efficacy for teaching in the context of a STEM-focused PBL classroom will be explored according to Bandura's four major forms of influence: mastery experiences, vicarious experiences, social persuasions, and physiological and emotional states (Bandura, 1995). These factors have been shown to strengthen self-efficacy in teachers and positively impact their practice (Chichekian & Shore, 2016; Morrell & Carroll, 2003).

*Article Three* describes the practice of asset mapping, which has traditionally been used in the field of social work and community development and applies it to the context of a STEM-focused PBL activity (Kretzmann & McKnight, 1993). The asset-based community development (ABCD) framework posits the following assertions: (a) every person has unique abilities and expertise, (b) every person is capable of making contributions to his/her community, and (c) every person has something that matters to them and that can serve as motivation to act and pursue change (Mathie & Cunningham, 2003). Extant research has demonstrated the possibilities of utilizing the ABCD framework in the context of problem-based learning (Stoddard & Pfeifer, 2018). The article *Asset Mapping in STEM Education: A Problem-based Framework for Educators* explores the benefits of an assets-based approach as well as provide practitioners with instructional tools to support the implementation of an asset focused PBL challenge.

The evolution of this dissertation began with an effort to describe the experiences of two African American girls as they participated in STEM-focused PBL in the context of a formal science classroom and the meaning of these experiences for their STEM identities. A lack of understanding of the basic tenants of PBL on the part of both educators tasked with leading problem-based STEM challenges in the formal classroom setting was evidenced in the data from *Article One* of this dissertation. Given that teachers serve as the linchpins of successful innovative education initiatives, understanding their experiences as they engage in these initiatives at the classroom level is critical. The next article in this dissertation examines PBL in a unique setting where the barriers evidenced in *Article One* are largely removed and focus shifts away from the student experience to better understand the implementation of PBL from the teacher's perspective.

Findings from *Article One* and *Article Two* demonstrate a failure to connect students' lived experiences to the scientific concepts and problems addressed in the PBL challenges. Without opportunities for learners to build upon prior knowledge that validates their experiences, developing and strengthening their identities as valued participants in the larger learning community is unlikely to occur. *Article Three* of this study addresses this issue directly with the construction of a framework that could support all of the educators described in this research to develop and leverage their students' assets through problem-based challenges.

## Methods Overview

This research utilizes an exploratory qualitative methodology. In *Article One*, a qualitative case study methodology was used to examine STEM-focused PBL as a sociocultural process to gain a deeper insight into participants' beliefs, attitudes, and experiences as they occur in a natural setting within a bounded system (Merriam & Tisdell, 2015). Case study research on identity can provide what Merriam describes as an "in-depth description and analysis of a bounded system" (1988, p. 40). *Article One* utilized forms of criterion sampling found throughout the literature on STEM education, particularly in case study research focused on science and STEM identity (Basu & Barton, 2007; Buck et al., 2014; Carlone et al., 2014). Data analysis for this study will utilize a grounded coding approach whereby thematic patterns emerged from the data after its collection. A case study protocol will be implemented to increase research reliability. Multiple sources of data were collected including interviews, observation field notes, and classroom artifacts (Yin, 2014). Data from this study included field notes and artifacts from two 45-minute classroom observations and descriptive transcriptions of interviews with two girls shortly after completing a STEM-focused PBL activity.

*Article Two* includes a reflexive thematic analysis that is defined for the purposes of this research as a qualitative research method for “identifying, analyzing, organizing, describing, and reporting themes found within a data set” (Braun & Clarke, 2006, 2021; Nowell et al., 2017, p. 2). This methodology was chosen for this study due to its flexible approach to the analysis of complex data as well as its usefulness in generating unforeseen insights and perspectives about participants operating within a distinctive situation or context (King, 2004).

*Article Three* provides an overview of asset-based community development theory and the asset mapping process and applies this approach to the practice of PBL in the context of a formal school setting. In addition, this article provides insight into the development of an instructional tool that can be used to support educators as they work to leverage every learner’s knowledge, resources, and skill sets to best meet the goal of a PBL challenge.

# CHAPTER TWO: DEVELOPING STEM IDENTITY THROUGH PROBLEM-BASED LEARNING: A CASE STUDY

Interest in experiential learning philosophies, instructional practices, curricula, and research has surged in recent years as governments and policymakers recognize the growing demand for skilled workers in STEM-related fields (U.S. Department of Labor, 2019). The importance of hands-on learning with real-world application in STEM has been recognized by organizations such as the Partnership for 21st Century Skills as a way to successfully prepare students for the future (2019). Experiential pedagogical approaches such as problem-based learning have been shown to foster student engagement in rigorous content through the use of authentic, high-value tasks and to integrate engineering and design principles across subject areas and grade levels (Blumenfeld et al., 1991; Capraro & Slough, 2013; National Research Council, 2000).

Utilizing a problem-based approach to teach STEM concepts can capitalize on students' preexisting funds of knowledge to promote STEM engagement and increase equity for traditionally underserved learners (Gay, 2010; González et al., 2005; Yosso, 2020). Previous research examined best practices to cultivate STEM identity in higher education settings to address the "leaking STEM pipeline" (Hachey, 2020; van den Hurk et al., 2019). A considerable body of evidence has suggested that children's science identities and future aspirations are largely formed between 10 to 14 years of age (Murphy & Beggs, 2005; Tai et al., 2006). An examination of the STEM identity formation process that youth experience during their early exposure to science presents a research gap (Carlone et al., 2014).

Students' STEM identity is indicative of the way they engage in the disciplinary community and demonstrate their self-efficacy and competence in STEM environments (Brickhouse & Potter, 2001; Carlone & Johnson, 2007; Tan et.al, 2013). Identity development can be viewed as the result of the interaction among psychological/ individual factors, cultural factors, and contextual factors of a learning environment (Collins, 2018). Carlone and Johnson's (2007) identity model views the development of science identity as intersectional and context dependent. In this view, developing science identity occurs gradually, considers individual traits such as race, gender, and ethnicity, and includes three interrelated dimensions: *competence*, *performance*, and *recognition* (Carlone & Johnson, 2007).

Research in science education for underrepresented youth has found that developing a strong science identity promotes students' persistence in STEM, improves academic performance, and increases the number of students who complete degrees in STEM-related fields (Atkins et al., 2020; Chang et al., 2014; Maton et al., 2016). An intersectional analysis of identity development can provide insight into how factors outside of the classroom such as family structure, gender, race, and socioeconomic status have the potential to influence how students experience and engage in STEM education (Delgado & Stefancic, 2017; Kim et. al, 2018). The purpose of the current investigation was to examine how underrepresented youth experience STEM-based experiential learning activities and the meaning of these experiences related to their STEM identities.

# Literature Review

## STEM-Identity: Formal and Informal Learning Environments

Studies on STEM identity, particularly among traditionally underrepresented students, have described several factors that positively contribute to identity development such as consistent and positive support from teachers, a learning environment that encourages scientific inquiry, and opportunities for students to apply scientific concepts to solve real-world problems (Chang et al., 2010; Espinosa, 2011; Miller et al., 2018). Research has also highlighted challenges that exist within the context of a traditional science classroom for these students. Obstacles include institutional norms that characterized girls' achievements in science as inferior to that of boys (Tan et al., 2013), "one size fits all" instructional approaches guided by science textbooks and standardized assessments (Green, 2006), and science educators who limit student agency by positioning themselves as epistemic authority figures (Carlone et al., 2014; Miller et al., 2018).

Further, common themes of race, gender, and socioeconomic status are evidenced in discourse related to STEM identity formation. Several studies specifically examined the impact of race, gender, and socioeconomic status on African American and Latinx youth (Barton et al., 2016; Evans & Winters, 2005; King & Pringle, 2019; Tan et al., 2013) as they transition into their various social, personal, and role identities (Merolla, et al., 2012; Tate & Linn, 2005). Research in science education of underrepresented youth has identified that developing a strong science identity promotes students' persistence in STEM, improves academic performance, and increases the number of students who complete degrees in STEM-related fields (Atkins et al., 2020; Chang et al., 2014; Maton et al., 2016).

Lave and Wenger's (1991) situated learning framework has been used as a lens to examine the relationship between the narrated (what is said) and embodied (what is done) identities of middle school girls as they participated in science activities in both formal and informal settings. A situated learning framework views the science classroom as a community of practice governed by a socially situated set of norms and rules for participation. It is within this community of practice that students begin to author their own identities as they participate in activities alongside their peers and with the guidance of their teachers. It is within these spaces that conflict may arise between students' narrated and embodied identities-in-practice as they engage in science classrooms that utilize a traditional pedagogical approach (Tan et al., 2013).

By investigating the relationship between the girls' narrated and embodied identities-in-practice, scholars have gained valuable insight into how underrepresented girls occupied identities-in-practice that either reinforced or hindered their future aspirations (Archer, 2012; Carlone et al., 2011; Tan et al., 2013). Findings indicated that many girls do well in middle school science classes and are capable of articulating their desires to enter a STEM-related career. However, the formal science settings in Carlone and Tan's studies did not provide the support necessary to help girls reconcile who they said they wanted to be (narrated identity) with what they did (embodied identity) in a formal science setting.

The structure, expectations, and opportunities provided by the formal classroom environment were shown to negatively impact the science identity development of female students who previously articulated an interest in STEM as well as those who did not (Carlone et al., 2014; Tan et al., 2013). Students encountered numerous obstacles as they began to develop an awareness of their multiple social identities (e.g., gender, race, sexual identity, socioeconomic status) and how these identities aligned with norms and practices of a school science classroom. Formal science classroom experiences have been shown to shape students' self-concept and impact how they process STEM-focused education and their motivation to pursue STEM as a career (Espinosa, 2011; Ortiz et al., 2020).

Institutional narratives reinforced by classroom teachers often supported recognizable social roles for girls that may have impacted the construction of underrepresented girls' science identities and limited their future science aspirations (Barton et al., 2016; Brickhouse et al., 2000; Tan et al., 2013). Gaining insight into how students engage in STEM education and the relationship between these experiences and the development of their STEM identities is critical (Carlone et al., 2014; Tan et al., 2013). Further, research exploring the situational aspects of STEM learning experiences and STEM-identity may provide valuable insight into how to best support sustained engagement in STEM-related activities for minority youth (Barton et al., 2016; Carlone et al., 2014).

Prior research has indicated that academic success in a traditional school science setting often does not promote stronger affiliation and deeper engagement in science in an informal learning environment (Carlone et al., 2014; Strong, 2016). Programs that demonstrated the most successful outcomes in terms of student participation and learning in STEM were high-quality after school activities that engaged students in tasks that were relevant and meaningful to them (Barton et al., 2016; Duran et al., 2013; King & Pringle, 2019). These STEM-focused learning experiences often involved participation from the outside community (Duran et al., 2013; Strong,

2016) in the form of experts providing background knowledge about a particular topic and the use of community spaces to house STEM-related activities (Barton et al., 2016; Duran et al., 2013; Tan et al., 2013). Building partnerships with experts from the immediate area disrupted students' ideas of what it meant to participate in science and allowed students to see themselves in that role (Strong, 2016).

STEM activities that take place in physical spaces that are informed by youth interests and ideas have evidenced a significant impact on their level of sustained engagement in STEM-based activities (Barton et al., 2016; Brickhouse et al., 2000; Strong, 2016, Tan et al., 2013). In these spaces, students no longer need to create their own science identities and instead can recognize that science is all around them and already embedded in their everyday lives (Archer et al., 2012). The most successful after-school STEM activities involved student participation in PBL tasks that were relevant and meaningful to their daily lives. Problem-based scenarios led to the creation of a useful artifact that addressed a community problem including anti-rape jackets, paper circuits, and pamphlets informing the community about green energy (Barton et al., 2016; Tan et al., 2013). These informal problem-based STEM learning experiences often required students to develop a deep understanding of a concept in order to apply it to real-world domains (Christensen et al., 2015; Duran et al., 2014).

The community aspect of a STEM-focused PBL approach provided students with a proximate social structure defined as the immediate context within which student identities could be enacted (Merolla et al., 2012). The intent of community based PBL was to offer a place where students could authentically integrate STEM concepts as they searched for innovative solutions to problems that were relevant and meaningful to their communities. The importance of these proximate social structures in influencing a student's level of commitment to his/her STEM identity, and the likelihood of carrying this identity from one situation to the next, cannot be underestimated (Merolla et al., 2012; Yarrison, 2016). The proximate social structures evidenced in informal science settings led to increased commitment and sustained engagement in STEM-related activities for minority students (Barton et al., 2016; Merolla et al., 2012; Tan et al., 2013). STEM-focused experiential learning activities and environments may provide much-needed support for minority youth who are often marginalized in the formal school science setting (Barton et al., 2016; LaForce et al., 2017). Further research is needed to examine how underrepresented elementary school girls' attitudes and perceptions are affected by STEM-focused PBL learning experiences (Connors-Kellgren et al., 2016; LaForce et al., 2017; Young & Young, 2017).

## Problem-based Learning in STEM

PBL, an instructional approach employed in STEM, is focused primarily on the inquiry process, whereby students explore, deconstruct, and reframe problems as they continually integrate new information. A PBL instructional approach requires teachers to take on the role of facilitators, affording students opportunities for self-directed learning as they work towards gaining a deeper understanding of ill-structured problems (Torp & Sage, 2002). For students, a STEM problem-based approach (a) fosters inquiry skills essential for a deeper understanding of STEM concepts, (b) develops analytical and creative thinking, and (c) supports collaboratively investigating problems they find relevant to their lives. PBL is an iterative process that provides students with opportunities to innovate in STEM-related fields. Authentic STEM-focused problems can provide learning opportunities that are relevant and useful to students' lives (Sutton & Knuth, 2017).

STEM-focused PBL experiences contribute to increased (a) content knowledge (Belland et al., 2009; Ertmer et al., 2009; Halvorsen et al., 2014; Parker et al., 2013), (b) student engagement (Bevan et al., 2015; Kuh, 2008), and (c) motivation for STEM learning (Barron & Darling-Hammond, 2008; Hand et al., 2003). A PBL approach to STEM education can provide students with an opportunity to make connections between concepts involving multiple elements of STEM in order to identify misconceptions, apply new knowledge to evaluate a problem, work towards finding solutions, and reflect on the process as a whole.

## Developing STEM Identity through PBL

Research that provides insight into the many barriers that impede STEM identity development for underrepresented groups in traditional school science settings is critical. The cultivation of STEM-identity requires an approach to teaching, learning, and curriculum development that validates students' cultural capital by situating the content within the social and cultural context of their lives. Positioning students' lived experiences, their interests, geographic locations, familial and cultural values, and social concerns as central components of a STEM-focused PBL approach is essential (Wright et al., 2016; Yosso, 2020).

The goal of a PBL approach in STEM education is to cultivate deeper learning by centering problems within a context that is meaningful to students (Baeten et al., 2010). Problem-based learning experiences can utilize students' cultural capital to solve authentic problems that students perceive as relevant and meaningful. The use of STEM-focused PBL as a tool to provide traditionally underrepresented groups with engaging and culturally relevant pedagogy has the potential to build STEM-identity, increase achievement, and strengthen future aspirations to attain careers in STEM-related fields (Banks et al., 2007; Moll et al., 1992; Wilson-Lopez et al., 2016; Yosso, 2020).

## Theoretical Framework

In an attempt to define aspects of the findings as either promoting or limiting identity formation, an understanding of how the term *identity* has been conceptualized in previous research is essential (Barton,1998; Brickhouse & Potter, 2001). In this study, the term identity is viewed from an interactionist perspective given the social nature of identity formation in a classroom setting (Carlone & Johnson, 2007; Gee, 2000). Given that data from this study included both observed behavior and narrated experiences, identity is recognized as a construct that is developed and performed within a particular context (Jones & McEwen, 2000).

Carlone and Johnson's (2007) identity model views the development of science identity as intersectional, context-dependent, and composed of three interrelated dimensions: *competence*, *performance*, and *recognition*. The use of this science identity model as an analytic lens for interpreting data in this study was chosen based on its alignment with the themes that emerged in the coding process. In this science identity model, identity not only encompasses how an individual perceives the learning task but also includes how successfully she/he performs it. Knowledge and understanding of STEM concepts (*competence*) strengthens identity only when it is *performed* and *recognized* by meaningful others whose acceptance influences how students perceive themselves in a scientific role.

Competence indicates a students' deep understanding of science concepts and content knowledge, and its development is often an internal and less visible process (Herrera et al., 2012). A learner's belief that she/he possesses the knowledge and skills necessary to successfully solve STEM-focused problem-based scenarios demonstrates an example of high competence. STEM-focus PBL can provide the learner the opportunity to apply knowledge and demonstrate competence while completing a task that she/he perceives as both relevant and meaningful.

## Purpose and Research Questions

STEM activities that involve problem-based experiential learning practices have demonstrated successful outcomes related to STEM-identity formation, particularly when contrasted with traditional classroom learning environments (Barton et al., 2016; Carlone et al., 2014; King & Pringle, 2019; Reyes, 2016). Lack of access to STEM-based learning experiences in K-12 environments is one of many possible factors contributing to the gap in STEM achievement that continues to persist for minority students attending low-income schools (Capraro & Slough, 2013; Barton, et al., 2017; Han et al., 2015).

The purpose of this case study is to describe the experiences of two African American girls from an alternative elementary school as they participate in STEM-focused PBL within the context of a science classroom and the meaning of these experiences for their STEM identities. This research site serves students who were previously unsuccessful in a traditional public school setting due to academic and behavioral challenges and 80% of the student body is African American. Insight from the data collected in this study may help practitioners better design and implement STEM-based active learning problems that promote STEM-identity formation for traditionally underserved and underrepresented groups.

Research questions for this study include the following:

1. How do two traditionally underrepresented girls attending an elementary school engage in a STEM-focused PBL activity?
2. How do the girls in this study describe their experiences, beliefs, and attitudes about STEM after participating in a STEM-focused PBL activity?
3. How do these experiences relate to the development of STEM-identity for these students?

## Methodology

The case study herein describes the experiences of two African American girls attending a K-5 elementary school as they engage in a STEM-based experiential learning activity and the meaning of these experiences for their STEM-identities. The case study examined STEM-focused PBL as a sociocultural process to gain a deeper insight into participants' beliefs, attitudes, and experiences as they occur in a natural setting within a bounded system (Merriam & Tisdell, 2015).

## Research Site

An elementary charter school in the southeastern United States was chosen for this case study based on its demographic composition (e.g., the majority are underserved and underrepresented) and access. The charter school had a high population of African American students; 80% African American, 19% White, and 1% Hispanic. Equally, the school has a high percentage of economically disadvantaged students with 84% living in poverty.

A new school-wide initiative was introduced and included a STEM-focused PBL day that was to take place once a week during the science block in every classroom. Problem and project topics varied across classrooms and grade levels and were created and implemented by the classroom teacher. Topics were chosen to align with content and standards being taught in the curriculum at that time or were decided based on current events such as rocket launches or hurricanes. The integration of PBL in science was an initiative that teachers began implementing three months prior to data collection.

## Positionality

The background, values, and beliefs of the researcher, and how the participant perceives these aspects of the researcher's identity, can affect how data is collected and the meaning that is made from it (Bourke, 2014). In the interest of reflexivity, the author's position must be made explicitly clear (Hammersley & Atkinson, 1995). My positionality began three years prior to this study. I was a founding teacher at the research site where I previously had been employed for over six years. As a result, there was a potential for my presence to influence the results of the study given my prior relationship with many of the students and teachers. My prior relationships may cause disruptions in the learning environment as I spent two years helping students regain control after explosive outbursts. These emotionally charged experiences had the potential to trigger certain feelings in the students. I attempted to control for these issues by selecting classrooms with teachers I had not worked with and student participants who I had never taught or interacted with in a disciplinary context.

## Data Collection

A case study protocol was used to increase research reliability. Multiple sources of data are required in case study research including interviews, observation field notes, and classroom artifacts (Yin, 2014). The data for this study included field notes and artifacts from two 45-minute classroom observations and descriptive transcriptions of interviews with two girls shortly after completing a STEM-focused PBL activity.  Audiotaping interviews while concurrently taking notes provided an opportunity to revisit what was said as well as reflect on initial impressions directly following the interview. Reflective journaling was conducted while initial impressions remained fresh and were used to develop ideas and concepts useful for coding (Halcomb &  Davidson, 2006).

An interview protocol (see Appendix A) was developed and analyzed alongside observation data and protocols. Interview questions focused primarily on how the students described their identities after engaging in what the teacher described as a STEM-focused PBL lesson. Questions elicited responses about the girls' self-perceptions, future aspirations, prior experience in STEM settings, and feelings about participating in STEM-related activities.

Interviews lasted approximately forty-five minutes and included an opportunity for the students to complete a Draw a Scientist (DAST) exercise. Member-checking took place after the interview concluded as the participants' responses to each question were paraphrased and repeated back to them for confirmation.

In addition, an observation protocol was developed and included both descriptive and reflective field notes. Descriptive notes incorporated primary data from direct observation, while the reflective notes included thoughts, questions, and ideas about what was being observed. Reflective notes were immediately transcribed through journaling to be used for later analysis.

## Validity

Validity was addressed through the use of descriptive transcription methods that provided metadata and reflection along with the verbatim transcriptions of each recorded interview (see Figure 1). Classroom observation notes included factors with the potential to influence the environment and a rich description and diagram of the classroom arrangement that demonstrated where and how participants were seated throughout the room. Given my knowledge and experience working with this population, issues regarding interpretive validity were less likely to arise, however cross-checking transcriptions and observation field notes (by the classroom paraprofessional and two doctoral students with backgrounds in education) took place as an extra precautionary measure. Data was collected from artifacts, observations, and interviews to allow for triangulation and provide the ability to gain multiple perspectives on each event.

## Data Analysis

Data analysis for this study utilized a grounded coding approach whereby thematic patterns emerged from the data after its collection. A theoretical framework was not selected prior to the completion of an initial review of the data (Grbich, 2013). A grounded coding approach is in contrast to *a priori* coding that utilizes existing theoretical frameworks to create predetermined themes as the basis of content analysis (Corbin & Strauss, 2014; Saldaña, 2015). Data analysis of verbatim interview transcriptions, protocols, and reflective descriptions were completed, and initial analysis codes were developed. Preliminary codes were based on the terminology used by the participants during interviews and descriptive interview transcriptions. Recurring patterns and themes were identified and became the general reference point throughout the analysis process.

After completing the initial stage of data collection, several codes related to STEM identity began to emerge. Carlone and Johnson's (2007) science identity framework was adopted as a flexible lens for future data interpretation as initial coding revealed multiple instances of words associated with the framework's three dimensions of science identity that included: (a) competence, (b) performance, and (c) recognition. Multiple reviews of transcripts, field notes, and artifacts were conducted in an iterative process to ensure evidence supported established codes. The relationships between codes were categorized and included several emerging themes. The coding process was repeated using descriptive and reflective field notes, protocols, and artifacts from two classroom observations.

Along with Carlone and Johnson's (2007) identity model, data analysis revealed additional frameworks that could provide a useful analytic lens. The juxtaposition of themes that emerged from the observation data (embodied identities) and the data from the interview transcripts (narrated identities) illustrated the various ways in which science identity can either be promoted or hindered through STEM-focused PBL in traditional science classrooms. Lave and Wegner's (1991) situated learning framework was utilized to address these findings by examining the relationship between girls' narrated and embodied identities-in-practice to provide insight into how best to support students as they attempt to reconcile any discrepancies that may arise in the process.

Research from the 1980s that examined children's perceptions of scientists discovered that a majority of children held a gender-stereotyped masculine image of a scientist and science-related professions (Kelly, 1985). As a result, the Draw-a-Scientist Test (DAST) was developed in 1995 and is an open-ended projective test that assesses children's conceptual images of scientists (Finson, 2003). A modified version of the DAST was incorporated into the interview portion of this study to investigate the images of scientists drawn by the students shortly after they participated in a STEM-focused PBL activity.

## Participants

This study included two African American females in grades 3 and 5, each from a different classroom and grade level. Criterion sampling, a purposive sampling method that involves the selection of participants based on specific and relevant characteristics, was used to select one student from each of the participating classrooms (Patton, 2002; Yin 2014). These participants attended a school designated an alternative school by district leaders. The school's mission focused on behavior management and crisis prevention for students whose behavior made it challenging for them to be successful in a traditional school setting. Given that this study took place at a school where over 80% of students exhibited behavior difficulties, criterion sampling was selected to ensure that the students chosen would contribute to the goal of the study by sharing their experiences participating in the STEM-focused PBL activities. The criterion for selection included students who were (a) willing to be a part of the interview process, (b) participated in the observed STEM-focused PBL lesson, and (c) were members of a traditionally underserved and underrepresented population.

Case study research on identity can provide what Merriam describes as an “in-depth description and analysis of a bounded system” (2015, p. 40). Participants in this study were defined by unique attributes (girls of minority status learning in a STEM context). For the purposes of this research, the units of analysis will be the students who are operating within the bounded system of their traditional science classroom (Merriam & Tisdell, 2015). The utilization of similar forms of criterion sampling can be found throughout the literature on STEM education, particularly in case study research focused on science and STEM identity (Basu & Barton, 2007; Buck et al., 2014; Brickhouse, 2000; Carlone et al., 2014).

## The Cases

### Taylor (pseudonym)

Taylor is a ten-year-old African American female attending an alternative charter school serving students who were previously unsuccessful in a traditional public school setting due to academic and behavioral challenges. At the time of this interview, Taylor was living with a teacher who worked at the school at the request of her mother. Prior to this arrangement, her mother, brother, and sister were all living out of her mother's car as she was unable to secure stable housing for the children.

Taylor is currently in the 5th grade and enrolled in at this charter school after leaving her previous school two years ago. At her former school, Taylor struggled to regulate her emotions and often disrupted the class with explosive outbursts that included yelling profanity, destruction of property, and running out of the classroom and away from school grounds. Prior to entering the charter school, Taylor earned Cs and Ds on her report card, scored a level 1 on her standardized state Math and Reading assessments, and was often removed from the classroom and suspended from school. As a result, she spent the previous year repeating the 4th grade at her current school where she earned a level 4 on both state assessments. Upon entering the school described in this study, Taylor was evaluated and provided with an individualized education plan (IEP) that identified her academic, social, and emotional needs and provided short and long-term goals to address areas in need of improvement. Taylor is now performing at grade level in all subject areas and has demonstrated improved interpersonal and communication skills according to the notes indicated by the teacher on her school report card comments.

Academically, Taylor demonstrated the most success with assignments that require lower order thinking skills such as memorizing, copying, and answering multiple-choice questions. These types of skills were assessed every Friday using tests from the ELA and math curriculum. When given an assignment that involves higher-order thinking, particularly in the area of reading comprehension or math word problems, she often refused to complete the assignment or walked out of the classroom to avoid it.

Nari (a pseudonym)

Nari is an eight-year-old African American female who transferred to this charter school from a northeastern state. She is in the third grade and has attended her current school for four months. Her mother was deported back to Africa when she was two years old. Nari reported that she has never met her mother but planned to visit her in the upcoming months. She has been raised by her father**,** also from Africa, and lived with her little sister. Nari reports having many other siblings she is not able to see. Four months ago, her father sent her to the southeast to live with her aunt and grandmother, and he stayed in the northeast for work. Nari attended this particular charter school because her aunt wanted her to be in a smaller school setting.

Nari has been described as a hard worker and a joy to have in a class by her teachers. She has a C grade point average. However, her teacher indicated she was meeting grade-level expectations in all subject areas that year. Nari struggled with focus and often required redirection despite her enthusiasm for learning. Standardized test scores were not available as she attended a private school before entering this charter school. Prior to her moving to the southeast, her father was very involved in her academic life. He would often bring her to the library to check out books related to science and engineering as he was employed as an electrician, and science and engineering was a shared interest. She resided with her aunt and grandmother who were both nurses at a local hospital.

# Findings

Results from this study focused on several aspects related to students' experiences participating in STEM-focused PBL, their beliefs and attitudes about science education, and the meaning of their experiences for the development of their STEM identities.

## Classroom Activities

Although being described as a STEM-focused PBL activity by the teacher, the instructional practices observed in Nari's lesson did not include these elements. Nari's activity consisted of a virtual lab presented synchronously to the entire class on a whiteboard positioned at the front of the room and required students to silently record answers and copy notes from the board. While Nari's teacher described the scenario as a STEM-focused PBL activity, data from the observation of the lesson evidenced a lack of understanding of the tenets of PBL on the part of the educator.

Taylor's classroom activity aligned more closely with the tenets of quality PBL (Blumenfeld et al., 1991) in that it incorporated opportunities for students to collaborate and use their content knowledge to think critically to solve a problem. In this lesson, students were asked to apply content knowledge about circuits and electricity that they had acquired in previous lessons to create a closed circuit using a Snap Circuit Exploration Kit. Students self-selected their groups and separated themselves largely according to their gender, resulting in two groups of only boys, one group of all girls, and one mixed group that included two boys and two girls.

The teacher rotated between the groups providing support when needed but spent over half of the lesson attending to a behavior issue with one of the students.

The design of the STEM-focused PBL task evidenced in this observation provided opportunities for students to experience competence and apply prior knowledge in a new way. The teacher structured the activity to require students to work in groups of four and allowed them to choose their own groups, which provided them with some agency in the process. When students were unsure how to proceed, the teacher encouraged them to ask one another before coming to her for help. By directing students to their peers to clarify concepts, the teacher enabled them to take on the role of an expert and afforded them opportunities to *perform* their *competence*, both conditions of Carlone and Johnson's science identity framework (2007), as they worked to clarify concepts for group members who needed support.

Taylor was a vocal and active participant in her group despite announcing her displeasure at having to work with others at the start of the activity. She took on the role of a leader by enlisting herself to manage the materials and explaining that only her science notes were to be used to find information that may be helpful to the group. She received *recognition* of her *competence* at multiple points throughout the activity. This recognition came in the form of the gratitude expressed by a member of her group for her help as well as from both the teacher and paraprofessional after her group was first to successfully complete the assignment.

In contrast, during Nari's lesson, opportunities to demonstrate competence and perform relevant scientific practices were afforded selectively and largely to only the male students. Within the context of the observed lesson, there were few instances where students were encouraged to actively participate in the lesson in ways other than responding to questions about content displayed on the whiteboard. Lack of opportunity to participate was particularly evident for the girls as demonstrated in the first twenty minutes of the lesson when three boys were called on to answer questions. Four girls, including Nari, had their hands raised and were ignored each time. Many of the male students called upon to respond did not have their hands raised at all.

In another instance, Nari was told to sit on the floor and she began rolling around on the ground in the front of the room. Her hand shot up in response to each question and she was repeatedly ignored by the teacher. When she was finally called upon to answer a question, three boys began an unrelated conversation amongst themselves that drowned out her response. Despite her answer being both correct and relevant to the lesson, she was not given an opportunity to perform and be recognized for her competence. A distinct pattern was evidenced throughout the presentation of the lesson whereby the teacher would pose a question, call on the same “go-to” male student to answer it, and then continue conversing with that student while the rest of the class sat quietly with their hands up. Towards the end of the lesson, Nari finally attempted to shout out her answer in frustration after her hand was repeatedly ignored. The teacher immediately interrupted her, went on to finish Nari’s initial sentence, and proceeded to remind her not to call out again.

This instance provided an example of Nari’s attempt to perform (e.g., communicate her understanding of the content by engaging in a scientific discussion) her competence (e.g., knowledge of science concepts) which resulted in her receiving no recognition (e.g., acknowledgment of her performance as “science person”) from her teacher, peers, or any meaningful other such as the paraprofessional or even myself. A similar scenario played out again thirty minutes into the lesson after the students watched a short video about planets and orbits. As it played, some of the girls pointed to the board excitedly while talking amongst themselves about the planets and how they orbit. At the conclusion of the video, Nari made a comment about how much she enjoyed it, and another boy in the class responded to her comment, which prompted a short discussion between the two of them as the class watched on. It was striking that this was the first-time students had the opportunity to speak to one another in what was described by the teacher as a collaborative STEM-focused learning experience.

The lesson concluded with one final video after which the girl in the front of the room asked a question and was told “shhh”, while the boys were allowed to talk over her and talk back and forth to one another. The “go-to” male student interrupted the girl and was not told to wait his turn and was instead praised for his answer. There was no evidence of the implementation of STEM-focused PBL as an instructional practice during the lesson despite the teacher describing it as such. In contrast to Taylor’s experience, in Nari’s classroom the role of the teacher was simply to disseminate knowledge, reinforcing what Freire (2000) refers to as the “banking method” whereby students are viewed as depositories and the teacher is the depositor of all relevant information. A one-way exchange of knowledge failed to promote critical thinking or any semblance of student agency in the learning process (Wiggan, 2011).

The narrative reinforced throughout Nari’s science lesson, that being that engaging in the practice of science is a one-way exchange of information that flows from the teacher to a selective group of students, served to limit the potential for Nari to experience competence and be recognized as a good science student. Gendered stereotypes were reinforced as boys were encouraged when they spoke out of turn to answer questions while girls were reminded to remain silent. In contrast, girls and boys were afforded equal opportunities to speak and be heard within the structure of the STEM-focused PBL activity in Taylor's classroom. Taylor was provided multiple opportunities to experience all three dimensions of Carlone and Johnson's (2007) science identity model: competence, performance, and recognition. Following these observations, interviews with both girls were conducted to better understand how they viewed their experiences participating in the STEM-focused activities as well as their perspective on their own science identities.

## Narrated Identities in Practice

Questions posed during both interviews focused primarily on how the students described their identities after engaging in what the teacher referred to as a STEM-focused PBL activity. Topics included their self-perceptions, future aspirations, prior experience in STEM settings, and feelings about participating in STEM-related activities. At the onset of the interview, Nari presented as a polite and reserved young woman, which was an image somewhat at odds with her observed classroom behavior. Throughout the STEM lesson, she demonstrated her frustration verbally by making exasperated sounds when she was ignored and with her body as she rolled around on the ground waving her hands in the air whenever the teacher looked in her direction. Although it is likely that Nari recognized my presence in the classroom during the lesson, she and I had no prior contact before that day, and she was unaware that I would be interviewing her at the conclusion of the lesson. It is possible my positionality as an unfamiliar person was helpful in this scenario as there were no previous shared experiences with the potential to influence her behavior towards me. She had the ability to define and describe her identity in whatever way she chose.

Unlike Nari, Taylor burst into the interview room with a smile on her face and confidently exclaimed, “Let’s do this.” She mentioned that she noticed me circulating throughout her classroom during the lesson. She then asked me who I was, what I wanted from her, and if this interview was for a grade. These questions set the tone for the remaining 45 minutes as Taylor attempted to steer the interview in any direction she chose, abruptly ending a line of questioning when she was no longer interested in the topic and expounding on unrelated topics when she felt inclined to do so. The juxtaposition between the attitudes and behaviors of these two students was evident in their initial exchanges and continued throughout the interview process.

## Self-perceptions

In order to understand the students’ self-perceptions after participating in a STEM-focused lesson, they were each asked to say a few things about themselves, describe themselves in three words, and provide a rationale for their choices. The first words Nari spoke in her interview described her future aspirations for a career in a STEM-related field and her family’s shared interest in animals. She explained:

> I like dogs and cats and want to become a veterinarian to take care of pets and have a whole bunch of dogs. We found another dog over the weekend and it was a bulldog and we also have a pit bull.

Three words Nari used to describe herself were "fun, kind, and generous" and she provided the following rationale:

> I am fun because I like to have parties and invite my friends and have sleepovers. I am kind because I help someone with work and when they are hurt. I am generous when I'm helpful and I help people a lot. Like Alex, he is usually in class drawing pictures of Ninjago, so I help him with his work because he needs help with his work.

Nari's description of herself demonstrates a positive self-image and that she largely defines herself in relation to how well she treats others. Here, her self-perception is based on internal aspects of her personality as opposed to outward appearances. It was interesting to note that none of her three descriptors referenced school-related topics such as intelligence, aptitude, or academic success. These omissions were not particularly surprising given the observational data reflected a lack of opportunities for her to perform and be recognized for her competence in science during the lesson that took place just a short time prior to the interview.

Taylor's responses to the same question were less detailed, more frank, and made it clear that she would be the one in control of the discussion. She explained:

> My name is Taylor and I am in the 5th grade. I go to this school here. I have two brothers and one sister and my favorite color is purple. I don't have nothing else to say about me now.

Three words Taylor used to describe herself were "smart, beautiful, and awesome" and she provided the following rationale:

> I'm smart because I get good grades and get hundreds on all of my weekly reading tests. I am beautiful because I know I am and people always tell me that. I am awesome. I don't know what else to say about that.

Similar to Nari's response, Taylor demonstrates a positive self-image. However, while Nari's narrated identity is defined by the things she *does* for others, Taylor's is largely defined by how others *respond* to her. She is smart not because she has a lot of knowledge but because she performs her knowledge for others through testing. She is beautiful because others tell her that is true, and she believes she is awesome but isn't quite sure why. In the context of her participation in a STEM-focused lesson, praise from meaningful others in the classroom provided her the recognition she required to view herself as successful in a science role.

Taylor's positive feelings about school frequently referenced her ability to do well on tests rather than acquire knowledge. When asked to list her academic strengths she responded:

> I feel like I am really good in reading and I used to be good at math. This year I'm not good at math anymore because it's just too much stuff you gotta learn. I'm just tired from all that stuff. It was good last year because I did 4th grade two times and so I got good grades because I already knew everything.

Taylor indicated that reading was her favorite subject because it was "fun", however she has no memory of what stories she's read or why she enjoyed them. She said she enjoyed reading because she was able to take a test each week and get all the questions correct.  When asked about her feelings about science she responded:

> I like projects but I hate working with other people because I like everything to be perfect and like my way. I get really mad when people don’t want to do the things the way I want them done. Sometimes I just stop working and sometimes I get really mad and don’t earn my points. I just want to do projects by myself so they are perfect.

All of these statements reiterate the idea that Taylor values her academic performance, often measured by a test or project grade, and the recognition she receives as a result of it. Of less importance is her perceived competence related to her knowledge and understanding of the material.

## Future Aspirations

When Nari was asked about her future professional aspirations and whether she knew anyone working in STEM-related fields. She responded:

> I want to be a vet. My grandmother works at the hospital and my auntie also works at the hospital and me and my dad have three dogs. I have been to my grandma’s job but not my aunties. I went with my aunt to get her shot at the doctor’s office. I also went to my grandma’s job at the hospital. My stepmom also came with me and so did my grandpa. My auntie comes back from work wearing a nurse’s shirt. My dad works as an electrician and he fixes electricity. I went to my dad’s job before and he had boxes all over. My baby sister came too and I had to carry her the whole time.

As evidenced in the data from this interview, Nari's family demonstrated a positive influence on her ability to recognize herself as a legitimate scientific person worthy of aspirations to attain a career in a STEM-related field. However, Nari's responses to questions related to her self-perceived academic strengths indicated her belief that she held a low level of competence in math as a subject area, which she felt influenced her ability to be a successful scientist. She explains:

> In math, when we do two-step word problems it is confusing because I need help with what operation to use. You have to do dividing and subtracting and sometimes both. I feel like I don't need math to do science but then I watched the movie about the first woman to go to space. I watched it and she was doing math so I guess you have to know it.

## STEM Experiences

When focusing only on the subject of science, Nari appeared to have a high degree of perceived competence. However, when math was included in the performance of science, her level of perceived competence decreased as evidenced in her response then asked about her academic strengths. Nari's reference to a film depicting a woman, particularly an African American woman, in a STEM context performing science through the use of math illustrates the potential influence that representative images may have had on her acceptance that mathematical skills are necessary for aspiring scientists.  The characters portrayed in the film can be viewed in the context of Carlone and Johnson's (2007) identity model as engaging the *performance* of science. The very presence of African American females serving as leaders in STEM-related fields in a mainstream film upends the traditional, prototypical narrative used to define how a STEM authority should behave, how they should look, and the way they should speak. Representations in media can promote STEM identity as they allow underrepresented groups to align themselves with a scientific identity (Steinke, 2017; Dou et al., 2019).

This sentiment is evidenced in Nari's description of the central character in the movie Hidden Figures:

> She went to outer space and she tried to save a person because he was heading to outer space where there was a meteoroid but before she could save him she had to do some math. The actor and her three friends had long black hair in a ponytail and she had brown skin.

A few aspects of this response are worth noting. In her response, Nari provides a detailed description of the physical traits of the female scientists portrayed in the film, including the color of their skin and the way they wore their hair. The very mention of these traits in response to an unrelated question indicates they are noteworthy and meaningful to her. One possible explanation for the salience of these details is just how novel they are in mainstream STEM-focused films, particularly those about space travel. The story of these African American female scientists may have provided an opportunity for Nari to better align herself with a science identity.

Embedded with the prototypical social context of a scientific community are specific expectations and norms required for participation (Shanahan & Nieswandt, 2009). In her response, Nari mentions that the female scientist had to help her male colleague avoid an impending meteor attack. Although subtle, the mention of this female scientist rescuing a male astronaut defied the role of the male as the prototypical savior. Nari's attention to this detail may be a recognition of its misalignment with the expectations and norms typically required to successfully participate in the scientific community. When asked about how she felt after she viewed the film, she responded:

> I felt excited because I had to watch that movie for science and I had to tell about someone in the past who was the first person to create or do something. The teacher said we could watch any movie and my dad chose for us to watch this movie.

In this instance, Nari's former teacher gave her the option to choose any movie about a trailblazing scientist for her project. The opportunity to exercise agency over her learning was then supported by the guidance of her father as he chose a movie, he felt would be meaningful to her. His potentially positive influence in the development of her STEM identity was further evidenced in the following exchange where she was asked what types of jobs she spoke about with her father.

> Interviewer: What kind of jobs does your dad to talk to you about [besides a vet]?
>
> Nari: He talks to me about becoming a lawyer or like the first girl to become the President or something like that.
>
> Interviewer: So your dad believes that you could do anything.
>
> Nari: He said I can do anything if I try.

Taylor was asked about her future professional aspirations and indicated her desire to become a lawyer. When pressed as to why she chose that profession, she indicated that she had seen lawyers frequently on TV (CSI and SUV were her favorite programs) and enjoyed watching criminals go to court and lawyers having to solve their cases. When asked what she believed lawyers did in practice, Taylor responded, “I don’t really know what they do but I want that. I want to argue in court.” Although she does not mention it in her interview, Taylor’s teacher indicated she spent a substantial amount of time with lawyers and in courthouses over the past year due to the custody hearings related to their family’s homelessness and the arrest of close family members. It is unclear whether these experiences influenced her response.

## Perceptions of STEM

As the interview commenced, both students were asked to complete a Draw a Scientist (DAST) exercise to gain insight into their perception of what a prototypical scientist looked like as well as the types of environments where she believed science took place (See Figure 1). They were each provided white paper and markers that included the four different options for skin tone (peach, light brown, dark brown, and black) in addition to the customary colors offered in a typical pack of markers. The same colors were offered in crayon form and the color white was added. Nari chose dark brown for the scientist’s skin color, she drew her in a pink shirt, and placed her within the setting of a traditional science lab complete with safety goggles and a beaker.

**Figure 1: DAST drawing by Nari**

Taylor’s illustration was of a male figure with white hair and a white lab coat standing next to a set of different color beakers. After completing the initial outline, Taylor realized how difficult it was to see the white crayon on the white paper.  She became visibly frustrated, walked across the room, picked up a black sharpie marker, and attempted to color around the white area (See Figure 2). When asked what she was doing the following exchange took place:

> Interviewer: Are you using black as the color of his skin?
>
> Taylor: No, you can’t see the white on the white paper.
>
> Interviewer: What color skin does he have? (sighs loudly)
>
> Taylor: It doesn’t matter what color skin he has. Why you ask me that?
>
> Interviewer: I am just trying to understand more about your drawing.
>
> Taylor: It don’t matter. He is brown then.
>
> She then takes a brown crayon and draws a brown face on top of the marker.

**Figure 2: DAST drawing by Taylor**

After drawing a brown outline for the face, she then picked up the black sharpie and colored over the entire image. When asked to describe what kind of person she thought becomes a mathematician or scientist, Taylor responded, “Old guys do. The ones with the white hair, I guess. Like the ones in that old ass movie when they go in a time machine. I seen it on TV.”

In contrast, when Nari was asked what kind of people she thought would become mathematicians and scientists. She responded, “people who are great at science.” In these words, lies the belief that science is an inclusive community of practice for all “who are great at science” regardless of gender, race, or socioeconomic status.  Nari’s statement demonstrates the influence of meaningful others on Nari’s science identity. Positive influences exist outside of the traditional science setting in informal STEM contexts and serve to mitigate the messages sent within the classroom that could limit her ability to develop and strengthen her STEM identity.

## Discussion

Research has consistently shown that school science settings have the potential to influence students' science interest and identity (Barton et al., 2016; Brickhouse et al., 2000; Wright et al., 2016). In this study, Carlone and Johnson's (2007) science identity model was used as an analytic lens to examine the experiences of students as they participated in STEM-focused PBL experiences. Through an examination of the relationships between the data and the larger research questions, factors unrelated to participation in STEM-focused PBL continued to emerge as potential contributors to the development of STEM identities for Taylor and Nari.

A problem-based learning approach to STEM education has been shown to promote a deeper understanding of underlying concepts as the learner is encouraged to build his/her own theories throughout the learning process (Wiek et al., 2014). When implemented in accordance with established research-based principles, a teacher utilizing PBL as an instructional approach acts as a facilitator supporting students as they work to solve complex problems that are often interdisciplinary in nature (Boud & Feletti, 1997). PBL in its authentic form can provide a proximate social structure for students to experience all three dimensions of Carlone and Johnson's (2007) science identity framework. Unfortunately, the absence of PBL principles in the traditional science classrooms in this case, as evidenced in observation data from both classrooms, has the potential to limit science identity formation for underrepresented youth in STEM.

One goal of a PBL approach to teaching STEM is to provide student opportunities to utilize their cultural capital to think critically as they work to solve problems they perceive as meaningful to their own lives (Moll et al., 1992; Wilson-Lopez et al., 2016; Yosso, 2020). Data from this study found that although activities were described as STEM-focused examples of PBL, they did not meet these criteria when enacted in the classroom. Neither teacher connected students' lived experiences to the scientific concepts and problems addressed in the lessons. In Nari's classroom, the lesson on space had the potential to engage learners in higher-order thinking and problem solving by incorporating a STEM-focused problem-based task related to space travel. Nari's description of the impact that the film Hidden Figures had on her perceptions of who can be a scientist illustrates how easily content knowledge about objects in the solar system can become relevant and meaningful to students.

Nari's space lesson followed a traditional instructional model where the teacher remained in the front of the classroom and disseminated information to all students who then copied her words into their notebooks. A unilateral approach to questioning was implemented so that all questions originated from the teacher and were answered by a student of her choosing. Observation data from Nari's activity demonstrated a lack of support within the proximate social space of her school science classroom as evidenced in her many failed attempts to demonstrate her competence and the negative feedback she repeatedly received as a result of these attempts.

Taylor's STEM-focused activity afforded more opportunities for students to perform competence and receive positive recognition from peers and the teacher. However, the task was not supported by a problem-based scenario that incorporated the interests and lived experiences of the students. The assignment lacked essential components of PBL such as an ill-structured problem to examine, the opportunity for students to explore issues related to the content, time and space for students to investigate solutions, or a means of presenting and sharing work with peers (Gwee, 2009; Laforce et al., 2017; Tawfik, 2014). The disconnect is clearly demonstrated in Taylor's response to a question about her experience participating in the STEM activity. When asked to describe what the task was about, she responded, "I used circuits to make lights work. We had to put them together, so it worked. It's like electric stuff." In reality, she simply followed the directions on the back of the Snap Circuit box.

Despite the positive structural aspects of the lesson (cooperative work, collaboration, autonomy, positive feedback), the activity failed to encourage the critical thinking and problem-solving benefits associated with problem-based experiential learning activities. Students' knowledge about electric circuits was not utilized to make the light turn on (competence). The only scientific practice they were able to perform was snapping pieces together (performance), and while groups were recognized by the teacher for successfully completing the task this recognition was not tied to their understanding of the content (recognition). The lesson presented a missed opportunity for students to experience any of Carlone and Johnson's science identity dimensions.

In Nari's case, proximate social structures found to contribute to her identity in this study did not involve aspects of the school science classroom, but informal contexts such as her family and their professional communities. The influence of proximate social structures, as evidenced in her references to visiting the STEM-related job sites with multiple family members, supported her as she enacted her identity as a person capable of taking on a science role (Stryker et al. 2005; Serpe & Stryker, 2011). The occupations of Nari's immediate family members and the role of parental expectations and encouragement appeared to positively impact her ability to view a STEM-related career as attainable.

One unexpected outcome of these results was that Nari, who was so often ignored and silenced by her teacher, expressed a stronger STEM-identity than Taylor's teacher who actively encouraged and positively recognized her participation throughout her lesson. For Taylor, the norms and expectations of PBL, particularly aspects such as collaboration, critical thinking, and problem-solving, did not align with her view that science results should be "perfect" and completed in isolation. It is within the context of a traditional science instructional model that her performance aligned best with the teacher's expectations (attain a high grade) and where she received consistent recognition in the form of praise related to her weekly test scores.

In contrast, Nari had a high level of competence in the area of science as evidenced by the correct answers she yelled out throughout the lesson and her unit test grades. However, she did not experience the benefits of her competence and knowledge of planets and orbits. She was not afforded an opportunity to successfully perform scientific practices that could have demonstrated her understanding, nor did she receive positive feedback from meaningful others during her science lesson. While her participation may not be recognized or appreciated in the classroom, school is not the only exposure she has to the scientific community. Through her connections to meaningful others, Nari had multiple opportunities to experience science in practice within informal spaces as well as professional settings. The norms and expectations of these proximate social structures better aligned with her own science identity, as evidenced in her interview responses and DAST artifact.

## Conclusions and Implications

A problem-based approach to learning is anchored in constructivist theories that view knowledge as created by the individual, shared through exchanges between the learner and his/her environment, and developed by communicating in a social environment (Barron & Darling-Hammond, 2008; Boaler & Staples, 2008; Crotty, 1998). When properly implemented, a problem-based learning instructional approach can provide opportunities for students to actively construct knowledge, exchange ideas with others in their peer group, and receive external recognition from meaningful others is necessary to strengthen science identity over time (Carlone & Johnson, 2007; Lave & Wegner, 1991). Unfortunately, despite both teacher's intention to implement a PBL approach, the classroom observations were not able to provide insight into how students engage in STEM-focused problem-based learning experiences as PBL was not evidenced in either teacher's instructional practice. Future research that examines potential barriers to the successful implementation of PBL, including teacher knowledge gaps and the constraints of a traditional science classroom setting, is needed so that students from traditionally underrepresented groups have the opportunity to experience quality STEM-focused PBL.

An analysis of the interview transcripts related to both students' experiences, beliefs, and attitudes towards science demonstrated the influence of people and settings outside of the school science classroom on their STEM-identity. Prior research has demonstrated the influence of media on identity formation, particularly its effect on science identity (Campbell et al., 2019; Fraser et al., 2014; Gauntlett, 2008; Steinke, 2017).  Both students in this study used references to television shows and movies in response to questions about future aspirations and perceptions of a prototypical scientist.  Popular culture influenced the students' perceptions of what a scientist looked like, where science took place, and the types of skills required to become a scientist. Best practices for incorporating stories and images of traditionally underrepresented groups in STEM settings through the use of media should be explored in future research. Findings can be used to inform instructional practice as well as the selection of instructional materials that support the development of STEM identity in a traditional science classroom.

# CHAPTER THREE: TEACHER SELF-EFFICACY AND INNOVATIVE REFORM

Educators and policymakers advocate to increase STEM content and to develop 21st-century skills such as the ability to think critically, collaborate, and problem-solve (Edmunds et al., 2017; Partnership for 21st Century Learning, 2019). Problem-based learning (PBL), a common experiential instructional practice, has been implemented in science, medicine, and engineering courses for over 40 years (Barneveld & Strobel, 2009). Problem-based learning is anchored in the constructivist theories from the early 20$^{th}$ century views knowledge as created by the individual, shared through exchanges between the learner and his/her environment, and developed by communicating in a social environment (Crotty, 1998). A problem-based approach in teaching has been utilized to create authentic student learning experiences that can be applied across the curriculum to support higher-order thinking skills (Aldabbus, 2018; Bell, 2010; Blumenfeld et al., 2000).

The implementation of PBL relies on teachers' expertise as they determine how and if constructivist-based instructional strategies will be applied in practice (Beck et al., 2000). Prior research suggests that teachers' self-efficacy beliefs influence their interpretation and implementation of curriculum and that these beliefs should be explored when investigating innovative reform efforts such as PBL (Pajares, 1992; Tobin et al., 1994). Problem-based learning initiatives require significant effort on behalf of educators as they must present the required content as well as facilitate students in the process of developing objects to demonstrate their knowledge and understanding of a given topic (Blumenfeld et al., 1991; Ravitz, 2010). The degree to which individual teachers are able to understand the concept of constructivism has also been shown to be a powerful determinant of whether a constructive approach such as PBL will be implemented effectively in the classroom (Oakes et al., 2000; Windschitl, 2002). Planning and implementing innovative instructional models challenge teachers to demonstrate the same persistence, effort, and resilience they often ask of their students. As such, teachers' self-efficacy beliefs and motivational orientations warrant consideration when exploring what factors may contribute to the success or failure of problem-based STEM initiatives.

Strong self-efficacy beliefs have been shown to impact the degree of persistence and effort educators dedicate to achieving a desired outcome in the face of adversity (Bandura, 2000). Examining self-efficacy in task-specific science, technology, engineering and math (STEM) environments may help researchers better understand teachers' self-perceptions about their ability to take a PBL approach to teaching STEM content and how these beliefs influence the implementation experience (Bandura, 1995; Pajares,1996). Teachers who demonstrate high self-efficacy beliefs feel more positively about implementing constructivist instructional approaches such as PBL (Chichekian & Shore, 2016).

The variation of teachers' self-efficacy beliefs related to STEM-focused PBL should be explored given the domain-specific and often interdisciplinary tasks embedded throughout a STEM-focused project. For instance, a teacher can have high efficacy beliefs about her ability to teach the mathematical components of the challenge but feel less competent in teaching the engineering aspects of the same project. Understanding beliefs is critical as self-efficacy has been attributed to the teachers' improved understanding of STEM concepts and content as well as self-confidence in their ability to incorporate constructivist pedagogical practices (Narayan & Lamp, 2010).

## Significance of the Study

Much of the extant research related to the implementation of PBL has examined the larger school-wide barriers to the successful implementation of STEM-focused PBL which included: (a) inadequate time to plan (Condliffe et al,, 2015), collaborate (Tamim & Grant, 2013), and deliver instruction (Blumenfeld et al, 1994); (b) lack of materials (Aldabbus, 2018); (c) classroom management concerns (Wang & Schwille, 2008); and (d) a school culture that places a high value on standardized test scores (Zhukova, 2018). An examination of a high-performing elementary school in its first year implementing a school-wide PBL initiative presents a unique opportunity for research as many common barriers to implementation should seemingly be removed.

Teachers serve as the linchpins of successful innovative education initiatives (Fullan, 2015). A myriad of factors play a role in how PBL is implemented and its sustainability as a pedagogical approach (Tsai, 2002; Windschitl, 2002). However, an examination of the sources and influence of an educators' self-efficacy warrants further exploration as new concepts may emerge related to the teacher experience that can inform the preparation and practice of future educators (Condliffe et al., 2015; Permatasari, 2019; Thomas, 2000).

An instructional position becoming increasingly popular in traditional public, charter, and magnet schools across the country is that of a specialized STEM teacher (National Science and Technology Council, 2020). This position, as defined for the purpose of this research, is one in which a single teacher provides all students in grades K-5 a year-long problem-based STEM course. Currently, there is an absence of research examining teachers who exhibit a strong degree of self-efficacy as classroom teachers transitioning to new instructional positions and leading innovative programs from the ground up. Therefore, understanding the experiences of the teachers engaged in problem-based learning initiatives at the classroom level is critical (Pecore, 2012).

## Research Aim and Purpose

This research describes the experience of a model teacher at a high-performing STEM-focused elementary school as she implements PBL in the first year of a school-wide STEM-focused reform initiative. It aims to examine teachers' self-efficacy and provide insight into ways to strengthen efficacy and increase confidence and motivation to implement innovative reform initiatives (Rosenholtz, 1989). Findings from this study may provide classroom teachers, administrators, district leaders, and state policy-makers insight into how school resources can be leveraged to select and support model teachers as they implement experiential reforms. This research may offer guidance to administrators tasked with choosing model teachers and school leaders to support and promote PBL reform efforts that are practical, productive, and sustainable.

## Literature Review

### Self-efficacy and the Teacher Experience

The ways in which educators interpret their practice in relation to student learning has been shown to directly influence their instructional choices (Ernest, 1989; Lumpe, et al., 2012; Nespor, 1987; Pajares, 1992; Richards et al., 2001; Roehrig & Luft, 2004). Self-efficacy theory is a well-established concept from the field of behavioral science and a valuable resource for examining instructional practice, particularly in relation to innovative reform efforts, as these theories aim to explain and predict future behavior (Posnanski, 2002; Ramey-Gassert et al., 1996). For the purpose of this analysis, self-efficacy is defined in terms of a person's perceived ability to achieve specific outcomes that are both task and situation specific (Pajares, 1996). In self-efficacy theory, a person's beliefs become a critical and explicit explanation for their motivation (Bandura, 1997). People with a strong sense of self-efficacy tend to welcome challenges, recover more quickly from setbacks, and develop a deeper commitment to interests and activities (Smith, 2001).

Teacher efficacy beliefs and beliefs about teaching and learning are often expressed through the enactment of instruction (Pajares, 1992; Peterman, 1993; Tobin, 1993; Tschannen-Moran et al., 2001). Prior research has demonstrated efficacious teachers are more inclined to innovate and are more comfortable operating outside of traditional pedagogical norms (i.e., teacher-led, textbook-based instruction), while teachers with lower degrees of self-efficacy tend to follow prevailing teacher-centered practices and resist taking risks-taking (Nie et al., 2012). Teacher efficacy is a particularly relevant theory when it comes to the implementation of innovative programs such as a dedicated STEM-focused PBL course as efficacy is considered dependent on a specific context and is often linked to broader innovation implementation efforts (Tschannen-Moran et al.,1998). Teacher efficacy has been shown to influence an educator's motivation to successfully organize, develop, and implement strategies in order to accomplish a specific goal in a particular context (Caprara et al., 2006).

In order for innovative teacher-led initiatives to be successfully implemented and sustained, it is necessary for educators to be self-efficacious in their approach to the initiative (Major et al., 2017). In addition, antecedent experiences have been shown to influence the development of teacher self-efficacy particularly in the area of science education (Dembo & Gibson, 1985; Skaalvik & Skaalvik, 2007). The relationship between self-efficacy and antecedent experiences related to science teaching and learning can illustrate how these experiences can either enhance or hinder teaching efficacy and can inform professional development programs designed to promote and support new initiatives (Ashton, 1984).

## Problem-based Learning in STEM Education

Problem-based learning (PBL) is a student-centered approach that requires learners to research a defined question, incorporate both conceptual and concrete knowledge throughout their investigation, and apply this new information to problem solve and develop solutions to address the issue (Savery, 2015). In this context, learning is often facilitated by a guide who supports students as they work to solve complex problems that are often interdisciplinary in nature (Boud & Feletti, 1997). A problem-based learning approach promotes a deeper understanding of underlying issues as the learner is encouraged to build his/her own theories throughout the process (Wiek et al., 2014).

Problem-based learning is based on the constructivist model of teaching and learning and has four main elements that include: (a) an ill-structured problem that is likely to generate a variety of hypotheses and approaches to problem solving, (b) a self-directed, student-centered approach to instruction whereby students largely determine the information they need to solve a problem and seek out relevant sources of information, (c) educators who assume the role of facilitators in the learning process, (d) and authentic problem that are connected to real-world contexts (Savery, 2015; Torp & Sage, 2002; Wells et al., 2009). A problem-based approach to

STEM education can provide students with an opportunity to make connections between concepts involving multiple elements of STEM in order to identify misconceptions, apply new knowledge to evaluate a problem, work towards finding solutions, and reflect on the process as a whole.

Problem-based learning in the context of STEM education is focused on the process of inquiry and prompts students to examine, deconstruct, and revise problems while continuously evaluating and integrating new information (Wells et al., 2009). A STEM-focused approach to PBL has been shown to (a) cultivate the inquiry skills necessary to develop a deeper understanding of STEM concepts, (b) develop and reinforce analytical and creative thinking, and (c) support social and emotional skills such as cooperation and collaboration through the investigation of authentic problems that are often interdisciplinary in nature (Barrows, 2002).

STEM-related fields such as engineering and medicine require adept problem solvers who are able to apply their knowledge and skills to analyze, design, and develop solutions to real world problems (Dischino et al., 2011). Problem-based STEM learning experiences can support students in developing these skills and provide educators an opportunity to link STEM concepts to local issues. By encouraging student engagement in the larger community, STEM-focused PBL challenges can also serve as a bridge to connect students to resources and networks they would not have access to otherwise.

# Methods

## Research Design

This study is one part of a larger exploratory case study that examined the implementation of experiential learning as a sociocultural process to gain a deeper insight into participants' beliefs, attitudes, and experiences as they occur in a natural setting within a bounded system (Merriam & Tisdell, 2015). Quantitative approaches to self-efficacy dominate much of the research in this area, with a majority of studies utilizing either experimental or correlational designs (Klassen et al., 2011; Tschannen-Moran & Hoy, 2001; Wheatley, 2005). Given the context-specific, multifaceted nature of the construct, quantitative methods may not always provide an appropriate framework for understanding the complexities of teacher beliefs and behaviors (Klassen et al., 2011; Labone, 2004).

In qualitative research, capturing meaning from the perspective of the participant is essential (Merriam & Tisdell, 2015). This study fulfills two essential tenets of qualitative research in that it includes a rich description of the context surrounding implementation and aims to understand the participants' behavior from his/her own frame of reference (Wolcott, 2008). While the aim of this inquiry is not to generalize these experiences to all teachers, it does seek to gain practical knowledge that can inform future practice and professional development related to experiential learning in the classroom.

This study was designed to examine the implementation of experiential learning as a sociocultural process to gain a deeper insight into the participant's beliefs, attitudes, and experiences as they occur in a natural setting within a bounded system (Merriam & Tisdell, 2015). The present study uniquely addresses teachers' self-efficacy in STEM-based PBL environments at a school in its first year of a school-wide STEM initiative. While evidence collected for this research included both direct observations and voluntary semi-structured interviews, this study will describe only the interview transcripts as a means of gaining insight into the implementation process from the teacher's perspective.

## Positionality

In qualitative studies, instruments such as surveys, inventories, and questionnaires are often supplanted by the researcher as she/he becomes the instrument used to mediate and collect the data (Bogdan & Biklen, 1992; Denzin & Lincoln, 2003; Hatch, 2002). Researchers across a variety of disciplines and contexts bring their personal values and beliefs into their work in the field. Qualitative researchers are compelled to not only acknowledge this fact but to also make known their values and beliefs and the potential significance they may have in the context of the study (Creswell, 2013). The background, values, and beliefs of the researcher, and how the participant perceives these aspects of the researcher's identity, can affect how data is collected and the meaning that is made from it (Bourke, 2014).

There are a number of factors that can impact how the data is mediated given the many years the researcher spent as an active participant in environments quite similar to the site of her study. It is important to make clear that the author approaches this study with her own ideas regarding classroom management, discipline, pedagogical methods, experiential learning, and teacher evaluation and training. Inevitably, her values, beliefs, and assumptions will affect her interpretation of the phenomenon.

A researcher-informant relationship is an additional characteristic of this study that has the potential to influence data collection and analysis. The author has observed the participating teacher in the past as part of her doctoral coursework and has developed a professional relationship with her prior to embarking on this study. It is also necessary to disclose that the author's children attend the school in this study and are both students in the participant's weekly STEM class.

In this reflexive thematic analysis, the positionality of the researcher has the potential to serve as both a strength and a challenge. The relationships and trust that have been established can potentially afford the researcher an opportunity to develop a deeper understanding of the perspectives and experiences of the participants. On the other hand, the researcher's preconceived ideas and assumptions can also influence the data analysis process. In an effort to bracket personal experiences from that of the participants, the researcher engaged in self-examination by writing a rich description of her own experiences prior to the data collection process (Marshall & Rossman, 2014).

## Data Analysis

A reflexive approach to thematic analysis underscores the active role of the researcher as a producer of knowledge and codes are understood to correspond to the researcher's interpretations of the patterns of meaning found throughout a dataset (Byrne, 2021). Through the use of reflective practice, researchers become aware of their positionality and reflect on the biases, assumptions, and expectations they bring to the research (Creswell, 2013; Johnstone, 2007). In the interest in reflexivity, the author's "position" must be made explicitly clear (Hammersley & Atkinson, 1995).

Bracketing, or epoche, exercise was conducted prior to data collection to ensure the researcher was aware of how her own experiences may have influenced the data collection process (Creswell, 2013). Achieving perfect epoche is a challenging task (Moustakas, 1994). However, the process of active reflection can mediate the extent to which the researcher's personal assumptions and beliefs interfere with their ability to delimit the topic of study from their personal experiences. A description of the researcher's own educational background and experience as an educator, trainer, and administrator is necessary as it directly relates to the phenomenon being studied. In addition, a discussion regarding how the researcher's past experiences could influence data interpretation is also required.

An interview protocol was used to increase research reliability and four semi-structured interviews were included in the data analysis process (See Appendix B). A reflexive thematic analysis, defined for the purposes of this research as a qualitative research approach for "identifying, analyzing, organizing, describing, and reporting themes found within a data set" (Nowell et al., 2017, p. 2), was chosen for this study due to its flexible approach to the analysis of complex data as well as its usefulness in generating unanticipated insights about participants operating within a distinctive situation or context (Braun & Clarke, 2006, 2021; King, 2004;). The aim of reflexive thematic analysis is to determine themes, or patterns of meaning, found throughout a dataset to gain insight into the perspectives and experiences of research participants and how these perceptions relate to the research questions presented in this study (Clarke & Braun, 2013). Thematic analysis is appropriate for this study given that its purpose is to capture, in detail, the teacher's complex reality as it unfolds throughout the process of implementation.

Braun and Clarke's (2006) theoretically flexible six-phase approach to reflexive thematic analysis was utilized in this study. Multiple approaches to reflexive thematic analysis can be employed throughout the course of a study. These variations include a deductive process, whereby codes and themes are informed by a theoretical framework and based on existing concepts, and an inductive approach to coding that is driven primarily by the content of the data (Braun & Clarke, 2020). This study includes a deductive theoretical approach to data analysis to capture relevant aspects of the data that addressed the aims of the research presented in this study.

An IRB was approved by the researcher's University prior to the data collection process. After University approval was obtained, a request for permission to conduct research at the school site was submitted to the district for consideration. The district granted permission for the study and allowed the researcher to collect data at the site. Preliminary data analysis commenced after initial interview data were collected, transcribed, and reviewed for accuracy by the participant through the process of member checking. Phase One of the analytic process followed in this study involved becoming familiar with the data through the process of listening and transcribing audio recordings, reading and rereading interview transcripts, and reviewing analytic memos recorded by the researcher shortly after the conclusion of each interview. Throughout this phase, data was continuously reviewed in an iterative process and notes describing potential areas of exploration were recorded.

The second phase of data analysis involved generating preliminary codes with the aim of organizing data in a more systematic and meaningful way. The process of open coding was implemented, and relevant data was highlighted. In the third phase of reflective thematic analysis, highlighted codes were examined and refined, and notable patterns and potential themes related to the research questions were identified. In the fourth phase of analysis, these themes were further reviewed to determine if they aligned with the initial codes and addressed the research questions. Themes were further refined during this stage with some being combined and others discarded.

Phase five involved review and revision of themes identified in the previous phase to ensure they were coherent and distinct and creating an informative name for each theme (Braun & Clarke 2012, 2020). The final phase of this process, producing a report, began once fully established themes were defined and a cohesive narrative was established.

## Research Site

The setting for this research study was a public elementary school situated in a large urban district in the southeastern United States. The school was originally built in 1926 and has been operating for over ninety years. The district the school belongs to is the 8th-largest in the nation and the fourth largest in the state. At the time of this research, the school was ranked 6 out of 125 elementary schools in the district based on their performance on statewide standardized tests. The student body is composed of approximately 450 students. The student population is 60% white, 35% black, and 5% other ethnicities.

The percentage of students achieving proficiency in Math was 71% (which is higher than the Florida state average of 57%) for the 2018-19 school year. The percentage of students achieving proficiency in Reading/Language Arts is 74% for the 2018-19 school year. The teachers at the school were all given a highly qualified rating the previous year and 50% have earned a master's degree. In addition, four teachers at the school had also earned national board certification.

The school was a member of a specialized innovative learning community for high-performing schools created by a southeastern public school district. Schools within the innovative learning community are afforded greater autonomy over curricular and instructional choices as long as these choices supported their district-approved innovation plan. The school was designated an Innovation School by the district for maintaining an A rating for multiple years and awarded additional funding for self-selected projects as a result. A dedicated STEM classroom was made possible because of the extra funding. The specific classroom setting is a dedicated STEM room that every student in the school will visit once a week outside of his/her regular classroom time. The room includes a digital whiteboard, three laptop computers, and a wide variety of technology tools.

## Limitations

There are several limitations in this study that are primarily related to its research design and issues of generalizability inherent in qualitative case study methods. As previously discussed, the role of the researcher in qualitative studies, particularly in the data collection and analysis phases, cannot be understated (Creswell, 2013; Marshall & Rossman, 2014). The researcher's personal experiences, beliefs, and assumptions about teaching and learning have the potential to influence the collection and interpretation of data and serve as a limitation of the study. Another limitation reflected in this study is the size of the sample itself. However, the purpose of qualitative research is to explore information-rich cases through the collection and analysis of large amounts of detailed data (Patton, 2002). This is best accomplished with a limited number of participants.

In addition, the participant selection in this study was not only based on the criteria for inclusion specified by the research questions, but also on ease of access and a prior relationship to the participant and the site location. While building relationships and developing trust prior to collecting data has been shown to positively impact the data collection process, the researcher's former familiarity with the participant and other staff members could serve to limit the study (Hatch, 2002).

## Participant

The teacher chosen for this study: (a) had attended a school-wide PBL summer training; (b) was determined by their administrators and peers to be model teacher in the area of PBL; and (c) actively designed, implemented, and managed PBL activities within the boundaries of a high-performing STEM-focused elementary school. The participant chosen for this study was in her first year of her new position as a specialized STEM teacher and was tasked with creating and implementing a PBL curriculum for all grade levels across the elementary school. Gaining insight into her experience developing and implementing PBL, particularly the degree to which her self-efficacy transfers from a traditional classroom to a dedicated STEM context, could support schools and districts as they work to build capacity for these types of innovative reforms in the future. The pseudonym Olivia was assigned to the participant by the researcher to provide anonymity and protect confidentiality.

## Participant Background

Teaching experiences, in both pre- and in-service contexts, along with an educator's childhood experiences in school, have been shown to influence their attitudes, beliefs, and behaviors in the classroom (Skaalvik & Skaalvik, 2007). Olivia attended public school throughout her entire educational career that culminated in earning her degree in elementary education from a large public university located in the southeastern United States. She has been teaching for ten years at various public elementary schools in close proximity to where she herself attended school. Her positions before becoming the research site's first STEM teacher included teaching fifth grade for seven years and fourth grade for one year at the same school where she is currently employed. In her teaching career, Olivia was always placed in testing grades that were very rigorous and largely focused on testing specific content knowledge. This was the first year the school offered a dedicated STEM special area course that every student visited once a week outside of their regular classroom time. Olivia was one of many educators at the school who volunteered for the position and was ultimately chosen by her administration and peers to lead the program.

When asked to describe her previous experience participating in or learning about experiential learning, she recalled memories from her elementary school experience as a child. Olivia discussed how rarely she recalled her teachers integrating projects or hands-on learning experiences into their lessons. During her time as a middle and high school student, Olivia recollected occasions when she was required to complete lab work or conduct experiments to test a theory or hypothesis and believed these experiences to be the one time she participated in hands-on learning. She was unable to recall a single instance when she was asked to complete a self-directed challenge or was required to collaborate with others to think critically about a real-world problem or create an artifact to help solve it.

Olivia recalled how she always enjoyed and excelled in math and science growing up. She expressed how much she looked forward to creating, building, and designing things. She expressed that despite having very limited opportunities to engage in experiential learning as a student, she found ways to do so on her own time. Designing and creating projects outside of school was something she continued to do throughout her life. Her impression that her school experience failed to provide her with the opportunities for collaborative, hands-on learning she desired shaped her belief that in-school science was something separate from the science that she experienced in her everyday life.

As an educator, Olivia has always had a love for math and science and believes she "could teach math all day long." During her time as a classroom teacher, she enjoyed implementing the types of projects and STEM-related activities with her students that she felt she missed as a child. However, she believed she was unable to successfully implement hands-on learning opportunities on a regular basis in her classroom due to time constraints related to covering all subject-area curricular material and assignments required by her district.

## Findings

The interview protocol topics discussed during the interviews with Olivia related to the implementation of PBL in a STEM-specific learning environment. The topics are presented in the following order: (a) beliefs about PBL, (b) barriers to PBL in a traditional classroom, (c) structure of a dedicated PBL courses, and (d) culture of a dedicated PBL classroom. After the presentation of the topics a discussion of themes discovered will follow.

## Beliefs about PBL

Problem-based learning is an instructional strategy guided by inquiry-based learning and is supported by variations of the constructivist theoretical framework (Bell, 2010). Prior research has indicated that teachers who subscribe to constructivist beliefs and who view students as active constructors of their own knowledge were more likely to implement student-focused instructional approaches such as PBL (Daniels & Shumow, 2003; Hashweh, 1996; Muis & Foy, 2010; Savasci & Berlin, 2012). When asked to define and describe her beliefs about PBL and her overarching goals for the program, Olivia expressed her view of PBL as an instructional approach that encouraged students to identify problems in their communities and design, create, and implement ways to address those problems. Olivia believed that PBL provided an opportunity for students to work through problems in a relaxed learning environment. She discussed the importance of incorporating the engineering design process and allowing students time to brainstorm solutions and share ideas openly. She explained, “projects are something you have to plan for, work together to create, modify as you go, and then make improvements.”

Olivia expressed concern that students in traditional classroom settings were rarely afforded the opportunity to be “truly independent” because teachers often provided them with step-by-step instructions for daily tasks. It was her belief that teachers should focus more on open inquiry and collaborative problem solving so students could learn that there is value in the process of trial and error and that not every project must be perfect. She discussed PBL as an instructional strategy that fit well with those goals and enjoyed monitoring progress and facilitating learning by "letting students take ownership of the process."

Olivia discussed the importance of supporting students throughout the inquiry process by reminding them that not all solutions will work and the revisions they would make are a necessary part of the process. She recalled instances as a teacher when she watched students as they worked to solve a problem with a solution she knew would not work and how she intentionally chose not to interfere in order to allow them to come to their own conclusions. Olivia viewed the PBL process as valuable and felt the skills embedded in the projects were transferable to subject areas outside of science and math. She also believed that PBL was a great way to engage students.

> "Students just want to stay in my room all day. I think a lot of what we do in here makes them excited to go back to their own classrooms**.** That is one of my goals. I want to get them interested and have them translate that interest into their own classroom when they are doing work in other subjects. I just want to get them curious about things because then they'll come to me and tell me about something they saw and it's not really something that's a standard or something that they, you know, have to learn. It's just making them curious individuals and that's how you make kids want to learn. When you are learning difficult topics in your regular classroom, if you have that curiosity and eagerness then you are more likely to be successful in it."

The overarching goal for the STEM-focused PBL program was described by Olivia as a way to make kids aware of the issues around them they may not have known about before and to empower them to feel like they could be part of the solution.

## Barriers to PBL in Traditional Classrooms

When asked about the challenges of teaching and learning through thematic problem-based projects during Olivia's time as a general educator, she described her concern that PBL did not, "hit all of the content and standards kids needed to know." She used her food desert unit to illustrate how PBL could be problematic when implemented during classroom teaching time.

> "So, if you're teaching, you know, doing some type of science standard and you're like trying to use food deserts to do it, you can relate that to science standards, but at the end the day is it really going to teach your students everything they need to know about plants or plant reproduction or whatever? You are not going to have time to fully teach all that content through problem-based learning, right? So, if you're in a general classroom, it's hard to do problem-based learning because if you do it then you've taken away time from your actual instruction of content. I mean, I guess nowadays you could really tie almost any project to standard, but does it really meet it? Is it really doing what you want it to do? It's all about time. Time is everything. You have to have *that* time built into your schedule."

Olivia explained that PBL was particularly difficult to integrate in the upper grades where students needed to have "solid content mastery" to be successful on state tests. She pointed out that in her dedicated STEM classroom she was not responsible for covering specific standards or content areas, therefore projects take no time away from teaching content, but rather enhance and reinforce the content covered in the classroom.

An additional obstacle she faced as a classroom teacher was creating a space where students felt comfortable making mistakes and revising their work.  In her past experience, Olivia would typically display a model of the artifact she wanted students to create at the beginning of a lesson to help them understand the objective of the assignment. In her STEM-focused PBL classroom, she noticed a high level of hesitation from students who were not accustomed to the design process of trial and error. She saw how difficult it was for them to stop trying to make their projects ‘perfect’ or identical to the model she presented.

> “I've learned to not really show a model because you immediately stop them from even thinking for themselves. Um, I mean they, even as an adult, like if I see a model all I can think about is what that looks like and it’s hard to think how to do it another way. Then you know, depending on how the students are doing, like if they're really struggling, I'll kind of help guide and get them started. In the beginning they felt like, well, my project isn’t perfect, so it’s all messed up. You know, it's ruined. And I'm like, you know, usually that is telling you this way is not working out. It doesn't mean you have to change your start over. Maybe you need to change part of it or you know, adjust certain things. So they've learned that. Now at this point in the year, I really don't see it as much as a problem.”

## Structure of a Dedicated STEM Course

In the school’s innovative STEM-focused PBL program, the topics for each semester’s challenge were decided during the creation of the school’s Innovation Plan submitted to the county. The STEM-focused school-wide plan included input from eight teachers and the assistant and head principals of the school. The team wanted each problem-based challenge to tie into either a concern in the community or in the world, with the overarching theme involving ways students can make a positive impact on the lives of people everywhere. Quarterly STEM challenges included creating a prosthetic limb for an animal, creating an app that serves the community, and addressing the issue of food deserts in low-income neighborhoods.

When asked how Olivia structured teaching and learning in the classroom across a semester, Olivia explained that for the first part of the nine weeks she focused mainly on small experiments and activities that directly aligned with the standards and that instruction was similar to a traditional science class. The second part of the semester included a problem-based challenge based on content students had previously learned. She explained she structured her units in that way because she felt it was important that students were provided with a solid foundation of science content while also having an opportunity to experience investigating and problem-solving issues related to that content.

When it came to weekly lessons, Olivia typically provided students with a set of materials they must use to design a solution to a given problem. At times, students would be asked to create their own list of materials. Olivia would often meet with groups to discuss why they chose the materials they did, if there were other materials that may have worked better, and why. She then had the groups create a blueprint or model of what their project would ultimately look like. She found this step to be crucial to, “get them thinking because they can easily draw a picture of what they want but they don’t realize, hey, well how do I actually make that?”

Olivia’s description of PBL as an instructional strategy indicates she understands the benefits of a safe “fail forward” learning space and believes it can be a tool for students to become more resilient and engaged with science topics. The idea of process over product aligned with her previously held beliefs about how she felt science should be taught if it weren't for the constraints previously mentioned.  She presumed that without those constraints the dedicated STEM course she created would provide a space that left room for students to learn, grow, and feel empowered by the process.

## Culture of a Dedicated PBL Classroom

Olivia described her belief that group work was an essential element of PBL and collaborative learning was at the core of the units she designed. When asked about her grouping strategies, Olivia explained she valued student voice and choice and allowed students to decide who they wanted to work with and where they wanted to sit in the room. However, she did recall times when she had to move students around in an attempt to ensure that groups were somewhat heterogeneous and that each member of the group had a role, ensuring individual success.

Collaborative learning through PBL was viewed as an opportunity for social skills training and a chance for Olivia to support students as they learn how to effectively communicate their ideas and provide feedback to others. When asked what communication looked like in practice, she indicated that students either raised their hands, engaged in partner talk, or had open group discussions where they were allowed to call out answers.  She explained, “I mean, I feel like constant hand-raising creates a lot of dead time. Sometimes I have to do a lot of talking because we only have 45 min and then I will ask students to raise their hands. Other than that, I just want everybody talking. It’s not complete chaos but it can get loud.”

## Discussion

Self-efficacy beliefs emerge from the cognitive processing of antecedent life experiences and the degree of self-efficacy a person experiences often relies on the accumulation of past successes within a task-specific context (Bandura, 1995). Extant research in this area has found that when self-efficacy beliefs and successful outcomes are compared, only those outcomes most closely tied to a specific task are predictive (Pajares, 1996). When it comes to innovative reform initiatives, which are typically led by those with little experience given the novelty of the innovation, those with higher degrees of self-efficacy have been found to be more open to new approaches than those with lower levels of efficacy in this particular domain. The following themes related to reconstruction of the model teacher's core practice that emerged from the data included: (a) the context-specific nature of self-efficacy in relation to mastery experiences, (b) the shifting roles and instructional goals in a problem-based learning initiatives, (c) and the enactment of constructivist beliefs through PBL.

### Domain-specific Mastery Experiences

Psychologists have identified four major sources of self-efficacy beliefs including a) previous experiences of mastering tasks, b) observing others' mastering tasks, c) messages from others (social messages), and d) emotions related to stress and discomfort (Bandura, 1995; Schunk & Pajares, 2002). According to Bandura, enactive mastery experiences whereby an educator experiences success implementing an innovative teaching approach and attributes the success to the enactment of that approach is the most significant source of self-efficacy (Bandura, 1995). These mastery experiences present one of the most compelling and persuasive sources of self-efficacy as they provide tangible evidence that success in a particular domain is possible despite the challenges inherent in the task (Bandura, 1995).

The implementation of an innovative STEM-focused PBL initiative required Olivia to shift her instructional goals to meet the needs of a much wider audience. To do this, Olivia drew upon her previous mastery experiences as sources of self-efficacy to overcome the obstacles she faced with her ambitious goal. However, the task-specific context of her efficacy beliefs in this instance had little to do with STEM or PBL. Rather, it was her prior success taking on leadership positions in her school and the fact that she was chosen by her peers to lead this innovative course that inspired her belief that she was capable of leading a school-wide innovative initiative such as STEM PBL.

The power of PBL lies in the inquiry process itself and success in each step is not easily quantified. In the past, Olivia's self-efficacy beliefs were bolstered each year she was recognized for her students' performance on standardized state tests. The context of her STEM-focused PBL course did not provide her with the same opportunities to experience mastery or recognition and she noted that this was a particularly difficult aspect of her new role. To mediate the anxiety she felt about assessing her personal success as the leader of this program, she focused on finding concrete ways she could embed content and skills into her challenges that could easily transfer to the traditional science classroom where measurable outcomes were more likely to occur. When PBL challenges were tied to classroom science topics, Olivia was able to take the STEM-focused PBL course she created and quantify its success. This was particularly true for the 5th graders who take a standardized Science test each year.

Olivia relied on her previous mastery experiences planning and delivering standards -based science lessons, as well as her accomplishments as school leader, to strengthen her self-efficacy beliefs in an attempt to transfer them more easily to the unfamiliar domain of her STEM-focused PBL course. However, the process of facilitating a problem-based design challenge not only failed to provide direct measures of personal success for Olivia, it also lacked visible outcomes that were easily understood by the outside school community or the larger community of social media. To strengthen her self-efficacy and stay motivated to persist in the face of challenges, Olivia decided to reframe her role and her instructional goals for the course.

## Shifting Roles and Instructional Goals

Olivia's background and experience prior to her new position as the STEAM teacher was as an upper grade classroom teacher tasked with delivering content in math, science, social studies, and ELA. As a classroom teacher, she set clear instructional goals for her students that were based on the standards and expectations of the school administration, and she became an expert in her grade-level content and skills. Olivia's new position required a shift in her instructional goals. The aim of her instruction was to continue to serve as a resource for her students, however in her new role as a dedicated STEM teacher she wanted to focus her efforts on supporting teachers as well. Olivia explained:

> "When teachers are beginning a new science unit, they have to focus on giving the students the content they need and not necessarily on working on projects. In my STEM PBL course, I hope to provide students with more elaborate activities based on the content that their teachers don't have time to cover."

Olivia's intention was to support the science content being taught in the classroom and the school's overall innovation plan through her quarterly STEM challenges. By doing this, she widened the scope of her role to include supporting both teachers and students. This effectively tied her course to their outcomes and provided her with the validation she was accustomed to as a result of past success. This strategy worked the first year this program was implemented. Scores on the standardized 5th grade science test increased with 64% of students passing with a 3 or above in 2018 to a 72% pass rate for 2019 (with roughly the same number of students testing each year 83 and 85 respectively).

Olivia had to adjust the nature of her self-efficacy beliefs, so they were no longer tied to earning praise for high test scores and having a professional identity tied so closely with results (which was a significant factor influencing why she was chosen for this position to begin with). However, tailoring instruction to the specific needs of multiple grade levels proved difficult given that Olivia taught every grade and each level had very different content to cover. The task of shifting from her traditional role as a source of support for the eighteen students in her classrooms to now supporting hundreds of students and dozens of teachers was challenging. To be successful, Olivia felt she needed to meet with each teacher to discuss the content and skills they would like her to reinforce. She utilized various sources of self-efficacy to address the demands of her new role.

Olivia discussed the challenges of "getting teachers on board" with her program. In her new role, she needed their support and their input in order to create challenges that reinforced concepts taught in the classroom. She knew from her own experience as a classroom teacher that some would view STEM challenges as unnecessary or additional work for their already overtaxed schedules. Olivia described how she relied on her reputation as a successful teacher and her years of experience in the classroom to encourage the teacher “buy in” she believed was necessary to shift her instructional goals to incorporate support for both students and teachers.

These mastery experiences allowed Olivia to begin to transfer her efficacy beliefs from one task-specific domain to the unfamiliar context of her STEM-focused PBL course. However, validation stemming from the successful completion of a PBL challenge often comes from the responses to the project from the school, larger community, and the world of social media. This focus on the end product may inadvertently bias the teacher’s focus away from the process of problem-solving and towards the creation of the artifact itself.

## The Enactment of PBL Instruction

A dichotomy appears to exist between the teacher’s beliefs about problem-based learning as an instructional approach, which she expressed as student-centered, fail-safe spaces aligned with constructivist principles, and her description of the enactment of PBL in her classroom. For example, Olivia expressed concern that students in traditionally structured classrooms were seldom presented with opportunities to demonstrate autonomy. She lamented that they were too often provided a set of explicit instructions that must be followed to successfully complete a task. However, her own practice revealed the enactment of a very similar structure whereby the rigidity of her instructions mirrored those of a typical classroom assignment.

By presenting preferred models of artifacts that could be used to solve the given problem, she did not allow students to use what they know to actively participate in constructing and negotiating knowledge or questioning their own assumptions in collaboration with others. A similar disconnect between what Olivia expressed as the affordances of her dedicated STEM course, particularly in regards devoting more class time to student-led discussion and exploration, and her desire to support the science teachers by reviewing their content at the beginning of each challenge. In this instance, the barrier to implementation was self-imposed.

It is possible that the strength of her self-efficacy beliefs from her many years of experience teaching math and science in a traditional classroom made it more difficult to let go of some of the patterns that led others to describe her as a model teacher. Her strong sense of self-efficacy was largely the result of her students consistently performing very well on standardized tests and recognition and praise from administrators, peers, and the district praised and recognized her efforts. In this case it appears that the teacher being highly efficacious in a similar context to that being studied negatively impacted her ability to carry out the reform with fidelity.

## Reconstructing Core Practice

Throughout the interview process Olivia discussed various constraints she faced related to the implementation of a problem-based approach to STEM. She mentioned that although she understood a fundamental tenet of PBL and the engineering design process was allowing students ample opportunities to try, fail, revise, and remake their projects, due to time constraints she was often unable to provide adequate time for “meaningful revisions.” As a result, she felt she often had to resort to simply telling them how the project could be improved instead of having them determine the issues and make the improvements themselves.

Time is still discussed as a constraint; however, it is interesting that it is a self-imposed constraint given Olivia is solely in charge of designing and implementing the course and the time table is up to her discretion. In her interviews, she demonstrated a desire to reconstruct her practice to align with her beliefs about PBL and the context of her innovative STEM-focused PBL course. However, she reverted back to her practice as a classroom teacher by creating PBL units with prescribed beginning and ending points that mirror a traditional science classroom structure.

This inconsistency between Olivia's beliefs and understanding about the principles of PBL and her instructional practice is evidenced in her discussion of the value of student agency and voice in choosing topics relevant to their lives. When asked how topics were chosen Olivia responded:

> "The administration, around eight other teachers, and I worked on creating the official Innovation Plan and picked the topics together. We decided as a school that each problem would need to tie into either a concern in their community or in the world, with the overarching theme being ways to make a positive impact on the lives of people everywhere."

It is interesting to note that while Olivia described the importance of teaching students how to identify real-world problems that are relevant and meaningful to them, the problems they would ultimately come to address were predetermined by the teachers and administrators before the school year began.

## Implications

### Mediating Implementation Challenges Through Social Support

The structure of nine-week challenges based on real-world issues tailored for each grade level was novel and incorporated tenets of a PBL framework. However, Olivia's classroom practice implementing STEM-focused PBL demonstrated the process of assimilation as she adjusted her previously held beliefs based on her experience as a classroom math teacher to better fit the context of the PBL reform initiative. Instances of accommodation, whereby Olivia's stated beliefs about teaching and learning were challenged and adapted to fit the tenets of PBL implementations, were not evidenced in her description of PBL or the execution of PBL lessons in her classroom. One possible explanation for why accommodation did not occur was because of the lack of social support given she was spearheading the program and was the only one teaching the course. She had no one to challenge her long-held beliefs about the nature of teaching and learning. Without a counter-voice of a respected peer, her inner voice continued to validate her practice and assimilate her teaching style into the vernacular of PBL.

### Social Resources: Peer Support and Collaboration

Prior research has demonstrated that social resources, including collaboration and support from peers, is an essential characteristic of teachers who have successfully reconstructed the core of their practice to align with constructivist-based reform initiatives (Spillane, 1999). In interview transcripts, Olivia described the importance of working in collaboration with other teachers and building relationships in the early years of her career as an educator. By observing and communicating with others who were successfully teaching the same population, Olivia began to believe that she could do the same. Observing her peers' success in the classroom made her feel that the goals and expectations she set for her students were possible.

Through her many experiences collaborating with peers, Olivia came to believe that her effort had the potential to influence outcomes and that determination and hard work could likely increase her odds of success (Muis & Foy, 2010). A positive relationship between her level of self-efficacy is evidenced by her understanding of how difficult it will be to accomplish her goal of developing and launching a STEM-focused PBL initiative and moving forward with the project despite the challenges it presented.

When discussing her first year in her new position, Olivia described herself as "an island" who is relatively isolated from the grade-level team whose support and collaboration she was accustomed to in her previous position. She recounted that one of the most significant challenges was that she only had herself to rely on for ideas and planning. She recalled that she "came from a team that worked really well together and it was really important to have that ... it was really important to have those relationships where you could bounce ideas off one another." She was disappointed that those sources of support were missing in her new role.

One way to mediate feelings of isolation for teachers taking on novel positions as a part of innovative reform initiatives would be to connect them to the larger education community where others are engaging in similar activities. In the case of this research study, there is a district-wide community of designated Innovation Schools that have each created a novel program led by a model teacher. Given innovation grants cover all subject areas, not all of these programs are STEM-related. Nevertheless, this form of peer engagement could serve to support and strengthen teacher efficacy in the context-specific domain of implementing innovative instructional approaches.

## Social Resources: Leadership and Administration

Additional social resources that may serve to mediate the challenges of implementing PBL through a dedicated STEM course include support from school and district leaders and administrators. Extant research has found positive feedback, both implied and stated, to be an essential source of self-efficacy that convinces a person that he/she is capable of successfully completing a task (Bandura, 1995; Leroy et al., 2007; Ramey-Gassert et al., 1996). Constructive feedback can maintain a sense of efficacy and help to overcome self-doubt. When examining the development of Olivia's self-efficacy beliefs through her interview, it is clear that she recognized the importance of the task-relevant feedback she received from her peers and administration throughout her career as a classroom teacher. Through her positive interactions with her school community as well as the district office, her degree of self-efficacy was enhanced, and she felt her insecurities were mediated and abated as a result. In her role as a classroom teacher, the process of interacting with those who provided her with multiple models of competency also served to strengthen her own self-efficacy beliefs (Hoffman, 2015).

When discussing her new role as the dedicated STEM teacher, interview transcripts indicate that Olivia had a positive view of her current administrative team and described them as both supportive and helpful. She recounted how both the Principal and Assistant Principal routinely checked in with her about what she felt was or wasn't working or areas where she felt she needed more support. She described the principal as "totally open and literally just kind of hands off like, you know, letting me do what I want. She sees that kids are excited about the STEM challenges and it's really giving them experiences that make them excited about school and learning, which is really the whole purpose."

Olivia described feeling grateful that her administration and peers had chosen her for this position and provided her with autonomy and freedom to create the program from the ground up. Unfortunately, while this "hands-off" approach provided Olivia the autonomy she craved, it did not help her to mediate the challenges of implementing the constructivist problem-based learning environment.

Prior research has demonstrated that factors such as recognition, praise, and support have been shown to strengthen teacher self-efficacy (Friedman & Kass, 2002). However, these forms of support were not sufficient in encouraging Olivia to examine and revise the core of her practice to align with the goals she set out for the program. A problem-based instructional approach requires students to collaborate and negotiate knowledge and concepts in an ongoing inquiry process. This same form of collaboration must be viewed as an essential component to build self-efficacy for educators tasked with implementing innovative models of teaching and learning. Autonomy in the absence of structured guidance from administrators and support from peers may not sufficiently mediate challenges, sustain motivation, or strengthen self-efficacy in context presented in this study.

## Future Research

Once the sources of highly efficacious educators are understood within the context of a specific constructivist-based reform initiative, researchers should consider ways to fill the gaps between theory and practice.   One possible next step to remedy the incongruities presented between teacher beliefs and understanding of a reform and their enactment of those beliefs in practice is to explore ways schools and districts can be structured to encourage ongoing, domain-specific support and collaboration from social resources within and outside of the school setting. Placing highly efficacious teachers in leadership positions for innovative reform initiatives is essential given the challenges inherent in launching a new program. However, it cannot be assumed that a teacher possesses a similar degree of self-efficacy for a task-specific domain such as implementing a constructivist problem-based inquiry pedagogical approach. As was the case with Olivia, peer feedback, support, collaboration, and idea sharing created the foundation for her high degree of self-efficacy as a classroom math teacher.

The same supports are also necessary, if not to an even greater degree, to mediate the challenges of revising core teaching practices to align with constructivist approaches. Findings from this study expand prior concepts and theories about teachers' self-efficacy in PBL STEM-based learning settings. The resulting key factors highlight implications for practice, provide direction for future research and inform practitioners and administrators interested in training and supporting model teachers to build capacity and sustain reforms related to experiential learning (Walsham, 1995).

# CHAPTER FOUR: ASSET MAPPING IN STEM EDUCATION: A PROBLEM-BASED FRAMEWORK FOR EDUCATORS

Learners in K-12 settings across the country bring to the classroom a wide array of educational experiences, cultural practices, and individual identities. The cultural differences learners carry into their learning environments have the potential to influence how they interact with their classmates and instructors as well as how they interpret course content, learning objectives, and assignments (Chita-Tegmark, 2012). Over the past two decades, considerable emphasis has been placed on standardized assessments in low-income schools as they are used to evaluate not only student performance but also educators' performance in the classroom (Goodwin, 2010; Mangiante, 2011). As such, deficit-oriented discourse used to explain poor academic performance in schools with high populations of low-income students has become commonplace and pervasive in academic literature and the hallways, offices, and classrooms in schools throughout the country (McKay & Delvin, 2016; Smit, 2012). An asset-based approach to instruction frames the diverse nature of learner experiences as strengths and provides opportunities for learners to express their individual identities through choice (López, 2017).

Poverty, unstable living situations, stress, nutritional deficiencies, and insufficient support from parents who must focus much of their energy on basic survival have a direct impact on student performance in the classroom (Jensen, 2009). Educators are often witnesses to the many challenges students face living in these conditions and observe the impact of these stressors on students' academic performance and social and emotional wellbeing. One way educators and administrators can resist the deficit-based narrative so often used to define low-income students and schools is to acknowledge and, if necessary, actively work to reframe their own perspectives. This shift in mindset will not alleviate the hardships so many students and families continue to face. However, recognizing students' lived experiences as acts of resilience and evidence of wisdom and resourcefulness, and not solely impediments to their future success, is one way to begin dismantling the prevailing deficit-focused narrative. Developing an awareness of the social, cultural, and digital assets students already possess that can be utilized in the learning process is essential for educators. However, it is equally important for the students themselves to recognize how their assets and experiences positively contribute to learning outcomes.

## Problem-based Learning: An Asset-focused Instructional Opportunity

Currently, many educators and policymakers advocate for the implementation of problem-based learning in K-12 classrooms to develop 21st-century skills such as critical thinking, collaboration, and problem-solving (Edmunds et al., 2017; Partnership for 21st Century Learning, 2019). A problem-based approach to science, technology, engineering, and math (STEM) education can foster student engagement in rigorous content through the use of authentic, high-value tasks and integrates engineering and design principles across subject areas and grade levels (Capraro & Slough, 2013).

Problem-based learning (PBL) is an instructional practice that views students' prior knowledge and lived experiences as valuable tools that can be utilized to solve problems that are both meaningful and relevant to their lives (Hung et al., 2008; Savery, 2015). Providing opportunities for learners to build upon prior knowledge can serve to validate their experiences and help develop and strengthen their identities as valued participants in the larger learning community (Darder, 2012; López, 2017). A problem-based instructional approach that positions students' lived experiences, their interests, geographic locations, familial and cultural values, and social concerns as central components of each challenge can utilize students' lived experiences to solve authentic problems they perceive as relevant and meaningful (Wright et al., 2016; Yosso, 2020).

Problem-based learning is a student-centered approach that requires learners to perform exploratory research related to an ill-structured question, utilize both conceptual and concrete knowledge during the course of their investigation, and apply their new knowledge to think critically about the problem and design solutions to address the issue (Savery, 2015). In the context of PBL, learning educator assumes the role of a facilitator or guide that supports students as they address complex problems that are often interdisciplinary in nature (Boud & Feletti, 1997). The problem-based learning approach encourages a deeper understanding of underlying issues as the learner builds upon his/her own theories throughout the process (Wiek et al., 2014).

Implementing an asset-based pedagogical approach can encourage learners to see themselves reflected in their work and can strengthen their identities as learners (Flint & Jaggers, 2021). Exposure to asset-based instructional strategies like PBL can encourage and support the identity development of traditionally underserved learners, particularly for those interested in pursuing careers where they are often underrepresented (Coleman & Davis, 2020). Problem-based learning challenges can provide educators an opportunity to leverage students' social and cultural assets and may also strengthen self-efficacy through the process of working toward a specific goal. Through the PBL process, learners can begin to recognize how their lived experiences have provided them with valuable, transferable skill sets that can be applied in academic and career settings.

PBL challenges can be structured in a way that can encourage learners to begin the process of recognizing the cultural, technological, and social capital they already possess. Constructing a framework that prepares educators attempting to develop and leverage their students' assets through problem-based challenges is the central focus of this article. The manuscript aims to define and describe common barriers students from under-resourced schools face as they work to strengthen and leverage their own capital in an academic environment.

Students often demonstrate the characteristics of persistence, resilience, agency in their everyday lives as a means of survival but are not taught to recognize these achievements or characteristics as assets that can be leveraged to succeed in academic settings. They may not be aware of the value of these resources and their role in the formal learning context of their school classroom. To address this disconnect, educators must explicitly counter this deficit narrative by encouraging students to reflect on their prior knowledge and skills to develop an awareness of their assets at each stage of the learning process. It is equally important that educators themselves become aware of the assets their students possess and, when possible, create a learning context where their knowledge and skills can be leveraged throughout the learning process.

## Asset Mapping: From Communities to Classrooms

Asset mapping is a concept that originated and was traditionally applied in the context of community engagement and first emerged from the field of social work and community development (Kretzmann & McKnight, 1993). The asset mapping process required community members to examine information to discover the unique strengths and resources of a particular community and explore ways that can be leveraged to solve problems, address community needs, and improve conditions for those who live there. The asset-based community development (ABCD) framework posits the following assertions: (a) every person has unique abilities and expertise, (b) every person is capable of making contributions to his/her community, and (c) every person has something that matters to them and that can serve as motivation to act and pursue change (Mathie & Cunningham, 2003).

The first step in an ABCD approach is to determine the community of study and research the assets already present in that community that can be leveraged to improve conditions for its residence. Once those assets are determined, the next step involves reaching out to community members to determine the assets they already possess and how these resources can contribute to a project they care about. The final step is connecting those with shared interests and assets and encouraging them to act collectively to meet a community need.

The ABCD framework operates in contrast to a needs-based approach to community development in much the same way an asset-focused perspective provides an alternative to a deficit mindset in the field of education. It frames the role of community members as active participants in the improvement of their communities and producers of community communication and collaboration as opposed to passive beneficiaries or consumers of information (Turner-Lee & Pinkett, 2004). Asset mapping in the ABCD process has traditionally been applied to analyze an entire community; however, adapting this framework to the field of education and make students and/or classrooms the units of study could achieve similar goals such as empowering participants, leveraging assets and working to create solutions to problems that are meaningful and relevant to them.

Extant research has demonstrated the possibilities of utilizing the ABCD framework in the context of problem-based learning to address issues of task-related bias in teams of students working together to solve engineering challenges (Stoddard & Pfeifer, 2018). In this context, students are prompted to identify life, work, and academic experiences and share the ways they believe these assets can best serve the interests of the group. Students then reflect and share what they aspire to learn and take away from their experience working on a problem with their teams. Responses are recorded to create an inventory for the group to refer to throughout the assignment. The authors' ultimate goal of implementing this framework was to develop more equitable, inclusive, and sustainable teams, particularly in STEM-related fields (Stoddard & Pfeier, 2018).

The process described above requires students to map their own assets by identifying their strengths in three separate domains, reflecting on what they hope to achieve, and sharing what they have discovered about themselves with their team. The participants in this study were undergraduate engineering students engaging in problem-based challenges that required team members to take on different roles and responsibilities. However, asset mapping is also applicable to younger students across a variety of educational contexts. The asset mapping process, informed by the ABCD framework, has the potential to extend beyond the focus of teamwork and be used as a tool that can empower both students and facilitators throughout all phases of problem-based learning challenges.

## An Asset-based PBL Framework

### Unrealized Assets: Everyday Obstacles and the Power of Student Ingenuity

Students from under-resourced schools and communities often possess unrealized knowledge and skills that can be leveraged through problem-based learning to build confidence and increase self-efficacy. In my ten years of experience working in schools with over 90% of students living in poverty (as determined by their free and reduced lunch status), I observed numerous instances of students successfully executing tasks in their everyday lives that were directly related to concepts being taught in the classroom. One example is a student who used online grocery platforms to plan and budget weekly meals to prepare for siblings while parents worked night shifts at a low-income job.  Another is a fifth grader who managed the weekly transportation-related needs and challenges for his family, including days when his parents did not have access to a car and he needed to find a way to get to school and get each of them to work, through the use of apps and GPS software. Students and families were forced to take on the task of coordinating carpools, planning public transportation routes, finding connections and bus stops where children could cross the street safely, as well as developing contingency plans if the bus was late or a ride never showed up.

The wealth of skills demonstrated in these seemingly mundane daily tasks (getting to school and work, preparing daily meals) involved high-level critical thinking skills. Families had to collaborate to develop a plan of action that often required each member to play an integral role in evaluating and executing contingency plans if problems should arise. In addition, these procedures had to be executed every day with multiple unpredictable roadblocks that needed to be averted (late bus, traffic, no money for gas, an unsafe person at the bus stop, parent's change in work schedule, etc.).  Challenges that students have overcome often lead to the development of attributes such as strength, resilience, and adaptability which provide them with valuable tools that could be leveraged to strengthen their identities as learners.

The day-to-day logistical planning that families without personal transportation must complete to put food on the table and provide their children with education requires communication, collaboration, critical thinking, as well as access to technology tools and devices. The digital capital these students carried into their formal learning environments includes not only digital literacy skills but an awareness and understanding of how to use the information to solve problems in a digital environment.

## Asset Mapping in the Context of STEM PBL

In a broad sense, a problem-based learning approach requires students to utilize 21st Century skills such as critical thinking, collaboration, and problem-solving. In the process of working through a problem-based learning challenge students will be asked to complete the following steps: (a) explore issues related to the topic of their problem, (b) take inventory of what they know about the problem and the gaps in knowledge they need to fill, ( c) locate resources and information about their the problem through research, (d) formulate hypotheses and analyze possible solutions, (e) support conclusions with evidence and share findings, and (f) reflection and evaluate performance and problem-solving skills.

Research has demonstrated that anxiety and discomfort that may arise from both students and facilitators when launching a problem-based learning challenge, particularly in its early stages (Wells et al., 2009). Anxiety and discomfort can be especially true for those students who are not aware of the knowledge, skills, and other assets they bring to the learning experience. Anxiety and discomfort can be mediated in this novel approach by providing space for students to recognize their prior knowledge, consider what gaps in their knowledge may exist in relation to the topic, and determine what further knowledge is necessary to accomplish a given task (Wells et al., 2009). The implementation of a problem-based asset mapping activity prior to introducing the topic of a new challenge may benefit students by increasing confidence and countering possible anxieties. In addition, it may also provide facilitators with valuable information about the assets students possess and encourage consideration of how they can be leveraged throughout the PBL process and beyond.

A framework for introducing a problem-based challenge must begin with an asset-focused approach. An essential component of the framework presented by Stoddard & Pfeifer is the students' identification and recognition of the assets they bring to the task (2018). Identification and recognition of assets takes place before any work can begin. Educators implementing PBL can empower students by encouraging them to recognize the assets they already possess and how they can be leveraged successfully in academic settings. To make these concepts self-evident to learners, the creation of an asset map that prompts students to consider various ways in which experiences from their everyday lives could be used as resources in the context of problem-solving should be administered in advance of introducing a new challenge.

The purpose of this initial step is to encourage students to consider aspects of their daily lives, relationships, experiences, and skills as assets in an academic setting. Considering assets is critical in under-resourced schools and communities where students have been shown to demonstrate lower degrees of self-efficacy in traditional classroom environments (Lofgran et al., 2015). Through this, students may be encouraged to consider how their assets may be leveraged to meet both their personal goals and the goals stated for the assignment. In prior research, education-focused asset mapping domains included categories such as lived experiences, work experiences, and academic experiences (Stoddard & Pfeifer, 2018). The community development model took an inside-out approach to its domains with individual assets at the center and expanding to citizen associations and ultimately widening to include local institutions (Kretzmann & McKnight, 1993).

The domains chosen for this initial asset map included in this study are context-dependent and designed for STEM-focused PBL tasks and include an examination of students' social, psychological, cultural, and technological assets. An asset-based approach to PBL instruction encourages learners to recognize their prior knowledge and skills and discover ways to leverage their word views, cultural perspectives, and lived experiences throughout the learning process. Prior knowledge and skills include the diverse ways they utilize technology in the context of problem-solving (Jones et al., 2010). Technology plays a vital role in supporting students as they hypothesize, think critically, investigate, and design solutions to problems and requires learners to use technology to not only consume knowledge but also to produce it (Amory, 2015; Kek, 2016). Technological assets include the ability to find information and evaluate information online (digital literacy) as well as apply technology tools to communicate and collaborate with others.

Psychological assets include attributes such as persistence, resilience, and adaptability, all of which are essential components of successful problem-solving (Seligman, 2002). Learners accrue social assets through their participation in social networks that afford them resources that would otherwise have been difficult to attain (Durlak & Weissberg, 2011). These resources can be in the form of mentorship by an expert in the learner's field of interest, access to technology and specialized tools, exposure to the norms and practices necessary to be successful in a specific field, as well as future networking opportunities. The last domain describes cultural assets, or learners' knowledge, skills, beliefs, and attitudes related to critical thinking and problem-solving (See Figure 3).

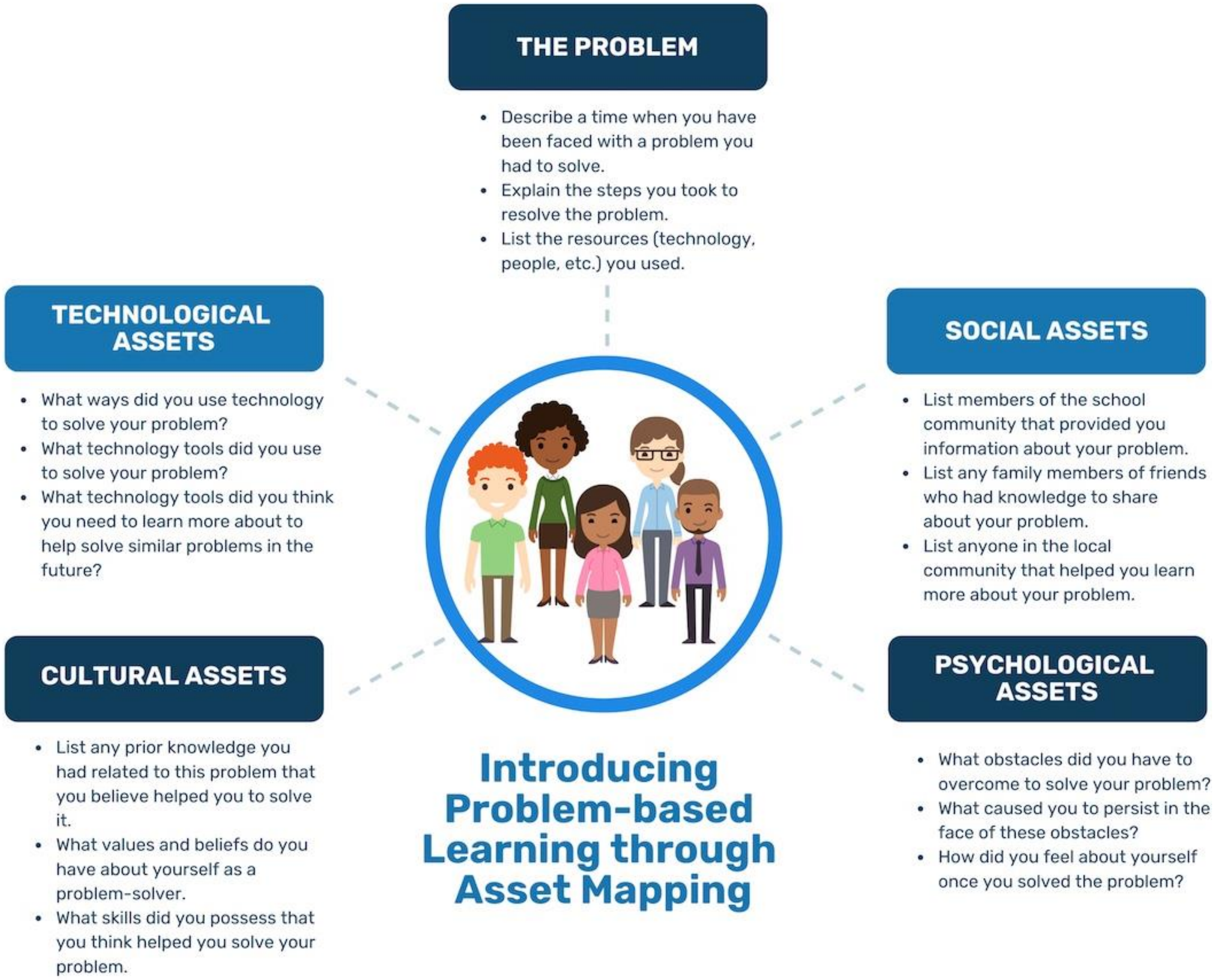


**Figure 3: Illustrated Model of the PLAM Framework**

The *Problem-based Learning through Asset Mapping (PLAM) Framework* can be incorporated at the beginning of the school year to provide the teachers with valuable information about the assets learners bring with them into a STEM-focused PBL environment. In this case, the overarching problem would be a student's personal experience problem-solving, and each map would be unique for every individual. The *PLAM* Framework can also be utilized after a specific PBL challenge has been introduced to the class. In this case, students would complete a map of the assets they possess that are directly related to the topic PBL challenge. The *PLAM* Framework could be a helpful tool for groups to help members ensure they are leveraging every learner's knowledge, resources, and skill sets to best meet the goal of the assignment.

In either case, this activity should not be a one-time event but an iterative assignment that students build on throughout the year. By completing maps in an interactive cycle, students are encouraged to acknowledge the assets they already possess and visualize growth in their critical thinking and problem-solving capabilities. Beginning a challenge by acknowledging the contributions that students have made and can continue to make to solve problems that are meaningful and relevant to them is the first step in implementing an asset based PBL framework. By completing the *PLAM* framework teachers may be supported as they actively work to counter deficit perspectives and cultivate their own asset-based mindset. However, additional modifications must also be made to the structure of the classroom and the role of each participant in the learning experience.

The need for educators to consider the assets that learners bring to problem-based learning was evident in Article one and two. For these reasons, the *PLAM* framework was developed. The process for developing the *PLAM* framework included: (a) an extensive review of the literature and (b) peer evaluation, and (c) expert evaluation. The framework based in community-based assets mapping, underwent multiple revisions therefore establishing the content validity of the framework.

## Shifting Instructional Roles in an Asset-based PBL Setting

When educators transition from a traditional instructional model to an inquiry-based approach such as PBL their role in the classroom must shift. In a traditional classroom, the teacher's role is to deliver information and assess student's ability to recall what they have learned via various forms of assessment. The teacher is the purveyor of knowledge and assumes the overriding authority in the classroom (Austin et al., 2001; Khalaf, 2018). In a problem-based learning context, educators are no longer the sole directors of the learning process. Instead, they serve as facilitators guiding students as they actively participate in the construction of knowledge. An asset-focused instructional approach takes the role and responsibility of the educator one step further. When moving towards an asset-focused PBL model, the teacher makes additional adjustments to his/her instructional practice such as encouraging students to recognize the assets they bring to the problem-solving process prior to guiding them through the construction, negotiation, and application of knowledge. Educators then use this information to empower students and create a sense of community in the classroom.

The role of the student must also evolve in an asset focused PBL context. The student transition is similar to that of community members from the ABCD model. In an asset-based community development approach, the role of a community member moves away from being a passive consumer of information and is considered an active participant and producer in the community building process (Kretzmann & McKnight, 1993). In a PBL instructional model, learners are co-constructors of knowledge and share ownership and responsibility for the learning process with their instructor. Through collaboration with others, learners are able to produce (as opposed to reproducing) knowledge. In an asset-focused PBL model, learners recognize their lived experiences as assets and view themselves as valuable contributors to the learning process. They are co-constructors of knowledge, and their diverse perspectives, beliefs, and problem-solving strategies are leveraged to develop viable solutions to a given problem.

## Discussion

### Building and Leveraging Assets Across Domains

#### Social

Students in under-resourced schools and low-income households often begin school with less social capital compared to their more affluent peers. Social capital is of particular importance when discussing experiential learning and STEM education for under-resourced schools and communities, as these relationships can connect learners to networks otherwise outside of their daily reach. In schools, teachers often provide the only link for students to connect with experts in their communities.

Providing opportunity and access to these networks is the first step to increasing social mobility for every learner. However, in order to benefit from these networks, students must understand their value and how to align issues relevant to their lives and with those of experts and mentors. Only through these connections can social mobility take place. Designing and developing problem-based challenges may provide opportunities for students to increase their social capital by incorporating tasks that link learners with experts in their field of interest or mentors they would not otherwise have access to.

Technological

Today's learners have been described as 'digital natives' by academics, policymakers, publishers, and the education marketplace for over a decade (Macdonald et al., 2017; Prensky, 2001). The digital native theory is the belief that all learners born at a time when technology was omnipresent, often referred to as "digital natives", are able to process information in a way that is fundamentally different from previous generations. It is offered as an explanation of the technological evolution of learning spaces in the digital age and used to promote educational software programs, curriculums, and digital devices (Bayne & Ross, 2007; Macdonald et. al, 2017; Romero et al. 2013).

Classifying an entire generation of technology users as 'digital natives' fails to recognize the diverse array of social, cultural, and digital assets these learners bring to the table (Macdonald et al., 2017). Further, it conflates aspects of digital assets such as the ability to find information and evaluate information online (digital literacy) with the capability to apply technology tools to communicate and collaborate with others to address a specific problem. The implementation of the asset mapping process prior to engaging in a problem-based task can help both educators and students recognize the technological skills students bring to the problem as well as the digital literacy gaps that may also exist. Problem-based challenges can be designed in ways that leverage existing technology skills to explore a problem and expand learners' technology experience and thereby increase self-efficacy.

Cultural

Many producers of educational materials have begun implementing an inclusive curriculum design approach across subject areas as evidenced by the inclusion of examples with subjects who have multicultural names, references to culturally specific scenarios (food, celebrations, language), and the depiction of culturally diverse images. While this is an overdue and necessary step to making students feel seen and valued in their classrooms, an educator's instructional practice can have a far greater impact on students' perceptions of themselves as learners than any change to the design of a curriculum.

Recognizing students' cultural assets in the classroom and across the larger school context has been shown to create a sense of connectedness and belonging for students and their families (Woolley et al., 2009). Asset-focused problem-based learning environments can provide an ideal context for home-school connections that strengthen students' belief and understanding of the valuable resources and skills they bring to the problem-solving process. To do so, PBL challenges should encourage students to view their classmates, families, and communities as resources to help them find solutions to problems that could improve lives and create positive changes in their community. Asset-focused PBL can provide the ideal environment for educators to highlight the skills and strengths that diverse learners bring to the learning process and how these cultural assets can be applied in an academic setting.

Psychological

Internal psychological assets are those behaviors, characteristics, and ways of affective thinking that guide individuals as they navigate life. In a classroom environment, psychological assets can be inclusive of one's social emotional competencies (Jagers et al., 2018; Reicher, 2010). Characteristics of resiliency, persistence, kindness, empathy, cooperating, and supporting others can help learners realize their personal contributions and commitment to responsibilities. In an assets-focused PBL environment, self-identifying and remembering one's psychological assets can support learners as they face new and challenging situations (Keyes & Haidt, 2003). Therefore, having students complete a self-assessment of their psychological assets and create a tangible reminder of these assets may benefit learners when they are struggling.

## Conclusion

The *Problem-based Learning through Asset Mapping* (PLAM) framework was created to counter a deficit-based narrative often used to describe students from under-resourced schools by encouraging both students and educators to recognize the valuable assets all participants bring to the PBL process. Exposure to asset-based instructional strategies like PBL can encourage and support the identity development of traditionally underserved learners, particularly for those interested in pursuing careers where they are often underrepresented (Coleman & Davis, 2020). Employing asset mapping in a PBL environment can position learners to consider what strengths they bring to a problem instead of focusing on not having an immediate answer to a complex question. Educators should commit to dedicating time to the creation or revision of a personal assets map in a tangible format. These maps can be referenced throughout PBL experiences. The broader implications of assets-mapping in the classroom include building self-awareness among learners of their assets which may aid learners to transfer their personal knowledge of their skills and expertise to other academic and social settings.

# CHAPTER FIVE: CONCLUSION

The aim of this research was to offer insight into the various challenges both teachers and learners encounter in the context of STEM-focused problem-based learning and provide tools for educators that may address barriers discussed throughout these studies. When properly implemented, a problem-based learning instructional approach can provide opportunities for students to actively construct knowledge, exchange ideas with others in their peer group, and receive external recognition from meaningful others is necessary to strengthen science identity over time (Carlone & Johnson, 2007; Lave & Wegner, 1991). In *Article One, Developing STEM Identity through PBL*, Carlone and Johnson's (2007) science identity model was used as an analytic lens to examine the experiences of students as they participated in STEM-focused PBL experiences.

In this study, students from two separate science classrooms were observed participating in what both teachers described as "STEM PBL activities." Significant variations in the implementation process were noted. While Taylor's activity included some opportunities for students to collaborate and use their content knowledge to think critically to solve a problem, these elements were absent in Nari's experience. In her lesson, the narrative that science is a one-way exchange of information that flows from the teacher to a selective group of students was reinforced on multiple occasions. Unfortunately, despite both teachers' intentions to implement a PBL approach, the classroom observations were not able to provide insight into how students engaged in STEM-focused problem-based learning experiences as PBL were not evidenced in either teacher's instructional practice. Both lessons lacked essential components of PBL such as an ill-structured problem to examine, the opportunity for students to explore issues related to the content, time and space for students to investigate solutions, or a means of presenting and sharing work with peers (Gwee, 2009; Laforce et al., 2017; Tawfik, 2014).

Further, the findings in this study also evidenced a clear failure by both teachers to connect students' lived experiences to the scientific concepts and problems addressed in the lessons. This missed opportunity was particularly unfortunate due to the social, cultural, and psychological assets evidenced in Nari's interview transcript. The knowledge, experiences, and skills Nari acquired through her relationships to proximate social structures such as her family and community were directly connected to STEM topics such as engineering and medicine. However, neither Nari nor her teacher connected these assets, which could have been leveraged to strengthen her identity and connection to STEM, to her experience as a student in a formal science classroom.

Similarly, when questioned about her future professional aspirations, Taylor described her wish to become a lawyer and argue in court. What she did not say, but what was known to the interviewer, was that Taylor had extensive first-hand experience witnessing lawyers argue in courtrooms as her family had been in the midst of a custody battle for almost a year. Her personal experiences witnessing lawyers make arguments based on evidence and presenting these arguments in front of an audience provided her with knowledge and skills that could be leveraged in the problem-solving process.

Strengthening the STEM identities of underrepresented groups remains critical to address the lack of STEM-related workforce participation of minority groups. In *Article One*, both students' experiences, beliefs, and attitudes towards science demonstrated the influence of people and settings outside of the school science classroom on their STEM identity. The findings from this research also demonstrate a lack of understanding related to the essential tenets of quality PBL by the teachers implementing these programs in the school observed in this study. Interventions such as additional teacher training, time, and support will be necessary for students to experience the benefits of participating in a problem-based approach to learning. Equally important for both teachers is developing an awareness of the assets their students bring into their classrooms and how they can be leveraged to strengthen students' identity and connection to STEM. *Article One* outlined the missed opportunities to recognize and incorporate students' experiences, knowledge, and skills in the PBL process. It also demonstrated the significant role educators play in the success or failure of STEM-focused PBL implementation.

*Article Two* shifted the focus away from student science identity to examine factors related to the implementation of PBL by a model educator in a dedicated STEM classroom. Teachers serve as the linchpins of successful innovative education initiatives (Fullan, 2015). Therefore, understanding the experiences of the teachers engaged in these initiatives at the classroom level is critical (Pecore, 2012). Teacher efficacy is a particularly relevant theory when it comes to the implementation of innovative programs such as a dedicated STEM-focused PBL course as efficacy is considered dependent on a specific context and is often linked to broader innovation implementation efforts (Tschannen-Moran et al., 1998). Therefore, teachers' self-efficacy for the enactment of STEM-focused PBL in the classroom was chosen for the second topic of *Article Two.* In addition to self-efficacy, the teacher's beliefs related to constructivism, perceived barriers to successful implementation, and classroom structure and culture were also explored.

Olivia was chosen as the teacher of study for the research outlined in *Article Two.* She had experienced years of success as a math and science teacher and was recognized in the school and within the larger district for her ability to raise student test scores in the areas of math and science as well as motivate and engage students in her classroom. The school where she worked had maintained an A rating by the state accountability system for multiple years, was recognized and awarded additional funding for being innovative, and employed teachers who were all rated highly effective in the previous year's evaluations. Unlike the teachers observed in *Article One*, Olivia was also formally trained in PBL methods and attended multiple research-based workshops led by academics and curriculum developers. She had the knowledge, time, resources, and support to implement PBL successfully and avoided many of the challenges teachers faced at the under-resourced school described in *Article One* of this study.

When Olivia described her beliefs about PBL as a constructivist-based approach, she expressed her view that it provided an opportunity for students to work out problems and make adjustments as they went in a relaxed learning environment. The overarching goal for the STEM-focused PBL program was described by Olivia as a way to make kids aware of the issues around them they may not have known about before and to empower them to feel like they could be part of the solution. However, not long after introducing the new program, she decided to widen the scope of her role to include supporting teachers in all grade levels by designing her challenges to reinforce the science content being taught in the classroom.

At this point, a dichotomy between Olivia's beliefs about problem-based learning as an instructional approach, which she expressed as student-centered, fail-safe spaces aligned with constructivist principles, and the enactment of PBL in her classroom became apparent. Olivia's self-efficacy beliefs were the result of her many years of experience successfully teaching math and science in a traditional classroom. The strength of her self-efficacy in that context made it difficult for her to let go of the instructional habits that did not align with the beliefs she expressed about PBL, especially when those habits are what led others to recognize her as a model teacher.

Olivia had the resources necessary to successfully implement problem-based learning that aligned with constructivist principles and avoided many of the traditional barriers to implementation discussed in prior research.  While Olivia's circumstances should have provided her with a far better chance of being successful than the teachers described in *Article One*, neither setting successfully positioned students' lived experiences, interests, values, and social concerns as central components of their challenges or utilized students' lived experiences to solve problems they perceived as relevant and meaningful. Further, despite the differences in student populations, varying degrees of teacher training in PBL practices, barriers and constraints to implementation, and administrative support within the school settings, neither *Article One* nor *Article Two* evidenced activities that actually met the criteria for STEM-focused PBL when enacted in the classroom.

All three educators failed to connect students' lived experiences to the scientific concepts and problems addressed in the lessons. Without opportunities for learners to build upon prior knowledge that validates their experiences, developing and strengthening their identities as valued participants in the larger learning community is unlikely to occur (Darder, 2012; López, 2017).  *Article Three* of this study addressed this issue directly with the construction of a framework that could help all of the educators described in this research develop and leverage their students' assets through problem-based challenges.

The *Problem-based Learning through Asset Mapping* (PLAM) framework was created to counter a deficit-based narrative often used to describe students from under-resourced schools by encouraging both students and educators to recognize the valuable assets all participants bring to the PBL process. Identifying assets in the early stages of PBL implementation may allow both educators and learners to mobilize these resources to encourage a sense of ownership and an enhanced commitment to the problem-solving process. Exposure to asset-based instructional strategies like PBL can encourage and support the identity development of traditionally underserved learners, particularly for those interested in pursuing careers where they are often underrepresented (Coleman & Davis, 2020).

While this PBL asset-focused framework was designed with students from under-resourced schools and communities in mind, its application is flexible and can benefit educators and students in a variety of learning environments and instructional contexts. The development of this framework was the direct result of the lessons learned from the first two articles in this study. Nari, Taylor, and Olivia’s experiences in the classroom were the inspiration for the creation of a tool with the capacity to increase both learners and educators' knowledge of one another’s assets and shift the focus away from learner’s deficits and towards their assets, skills, and strengths.

In the case of Nari, the strong influence of proximate social structures supported her as she enacted her identity as a person capable of taking on a science role (Stryker et al. 2005; Serpe & Stryker, 2011). The STEM-related occupations of Nari’s immediate family members, which included nurses and electricians, along with the parental expectations and encouragement she received, appeared to positively impact her ability to view a STEM-related career as attainable. In her interview, Nari did not express an awareness of how her social, technological, psychological, and cultural assets could be applied to solve problems in the context of her PBL classroom challenge. Both Nari and her teacher would have benefited from having an awareness of these assets as this knowledge has been shown to positively impact learner success, achievement, behavior, and motivation (Eloff & De Wet, 2009; Starkman, 2006). It is equally important for educators tasked with implementing innovative reform initiatives in the classroom to develop an awareness and knowledge of their own assets and how they can be leveraged to positively impact the learning experience for all participants.

Olivia was a model teacher with strengths and accomplishments that had been recognized by others throughout her career. She felt highly efficacious in STEM-related subjects such as math and science and her self-efficacy was strengthened each year as her standardized test scores demonstrated her ability to cover content effectively. While she had an awareness of her own assets and how they could be applied to the context of her dedicated STEM course, assets she described as salient were narrowly focused and often unrelated to the task of spearheading an innovative inquiry-based program for students across grade levels. The experience of deliberately considering a wider range of possible assets, such as those included in the *PLAM* framework, could lead to increased feelings of empowerment, connectedness, and value.

Lessons learned from each of the articles described in this study can be used as the impetus for the creation of a new vision for PBL, one that reframes its goals and opens up the possibility for this instructional strategy to truly strengthen identity in STEM, increase teacher self-efficacy to implement inquiry-based reform initiatives, and leverage students' social, cultural, technological, and psychological assets to solve problems in their communities. This approach does not encourage educators to ignore students' existing needs, often referred to as deficits, and focus only on assets. As a classroom educator for over a decade, I understand first-hand the importance of assessing student needs and developing ways to best address them to support their success. This approach, and the supporting *PLAM* framework, do not ignore the realities, expectations, and constraints teachers face delivering instruction each day. Rather, it outlines a paradigm shift, inspired by principles of positive psychology, that moves the primary goal of instruction away from addressing student deficits and toward an asset-based approach that emphasizes what is positive and what works.

If problem-based learning is to continue to be a useful instructional strategy for supporting self-directed learning, collaboration, critical thinking, and problem solving it must continue to evolve. The implementation of PBL has the potential to truly empower students to become agents of change to their communities. To accomplish this goal educators must recognize the assets students bring to the learning process, make these assets knows to the students, and work together with students to leverage their lived experiences to solve problems that are relevant and meaningful to them.

Future research will include analyzing the use of the *PLAM* framework in both STEM-dedicated and traditional classrooms. A possible intervention would be designed to first conducted professional development experiences for teachers to learn the framework and practice it to solve their own problem. Creating opportunities to build efficacy utilizing the *PLAM* framework could support the future implementation of the framework for PBL STEM-focused learning experiences.

# APPENDIX A: STUDENT INTERVIEW PROTOCOL

**Interview Protocol:** The purpose of this interview is to gain insight into the experiences, beliefs, and attitudes of two traditionally underrepresented elementary school students after participating in a STEM-focused PBL activity within the context of their school science classroom

| Data | Question | Prompts & elicitations |
|---|---|---|
| To break the ice and provide some background. | Tell me a little bit about yourself. | Age<br>Teacher<br>Amount of time at this school and reasons no longer at home school |
| Girl's self-perception/identity | If you could describe yourself using three words, what would they be? | Three words<br>Rationale for each word |
| Field/career aspirations | Tell me about what you hope to be when you grow up | If STEM related ask if she knows anyone (and if so, who) working in that field. |
| School subject preferences | Tell me about your favorite subject in school. | What do you feel you are good at? |
| Feelings about STEM related subjects | Tell me your feelings about subjects like math and science. | Positive<br>Negative |
| Experience in STEM setting | Tell me about a time you participated in a math or science activity. | What did she do<br>Role in the group |
| Student description of how the envision a STEM participant | Please draw an image of a scientist or a mathematician. | What type of people does she think become scientists and mathematicians? |
| Experiencing in STEM based courses | Tell me about your experience as math and science student? | Positive experiences<br>Negative experiences |
| Member-checking | Paraphrase what I heard about main topic:<br>1. how she described herself<br>2. her feelings about STEM-related subjects<br>3. her drawing of a scientist<br>4. her experience as a student<br>Ask for response | |

# APPENDIX B: TEACHER INTERVIEW PROTOCOL

**Interview Protocol:** The purpose of this interview was to understand an elementary school teacher's belief regarding the culture of her school, her role as a teacher, her level of understanding and experience with project-based learning, and the challenges or constraints she faced implementing PBL in her classroom.

| Data | Question | Prompts & elicitations |
|---|---|---|
| To break the ice and provide some background. | Tell me a little bit about yourself. | Age<br>Race<br>Primary position this year<br>Years teaching<br>Years teaching at current school<br>Highest degree held |
| Description of school culture/climate | I define culture as: the unwritten rules, traditions, norms, and expectations held by a group of people that shape beliefs and behavior over time.<br><br>How would you describe the culture/climate of your school? | How did you come to understand the culture of the school? Was it explicit or implied?<br><br>What are some of the school's unique features?<br><br>How has your school changed since you began teaching? |
| Beliefs about role as the teacher | How do you describe your role as a teacher? | Does your role change based on factors such as type of activity, subject area, and/or teaching objectives? |
| Classroom management style | What is your classroom management style? | How do you group students?<br><br>How do students participate in discussions (hand raising, calling out, some other form)<br><br>How is the seating arranged in your classroom (flexible, desks and chairs in rows, in groups, etc.) |
| Determine understanding of what a project is | What is your definition of a project?<br><br>What are some examples of projects you have done with your students this year? | |
| Teacher beliefs about project/problem-based learning | I define PBL as a model that organizes learning around projects that typically involve complex tasks designed to address challenging questions or problems. The structure of PBL typically allows student to work on a project for an extended period of time and present findings/products to other peers and adults.<br><br>Please define and describe what PBL means to | What do you consider the goals of PBL? |

| | | |
|---|---|---|
| | you? | |
| Experience with PBL teaching | How much experience have you had with PBL?<br><br>To what extent do you try to use or implement projects in your classroom? | Have you ever taught using a PBL model?<br><br>What differentiates PBL activities from other types of classroom activities?<br><br>Examples could include reflection/goal setting, voice and choice, collaboration. |
| Feelings about PBL | Do you think PBL is a effective? Why or why not? | Is is more effective in some areas relative to others?<br><br>How do you measure its effectiveness?<br><br>How do you compare a project-based approach with —traditionall teaching? |
| Description of PBL challenges | What do you think are the challenges in organizing a project in your class? | What are some constraints which may prohibit you from implementing a project- based approach? |
| Member-checking | Paraphrase what I heard about main topic:<br><br>1. Description of school climate<br><br>2. Beliefs about teacher role and management style<br><br>3. Beliefs and understand related to PBL<br><br>4. Experience implementing PBL<br><br>5. Challenges of PBL | Do you have any other comments to add about Project-based Learning or teaching in general? |

# APPENDIX C: IRB EXEMPTION

**Institutional Review Board**
FWA00000351
IRB00001138, IRB00012110
Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

UNIVERSITY OF CENTRAL FLORIDA

EXEMPTION DETERMINATION

September 28, 2021

Dear Laurie Campbell:

On 8/14/2019, the IRB determined the following submission to be human subjects research that is exempt from regulation:

| | |
|---|---|
| Type of Review: | Initial Study, Initial Study |
| Title: | Exploring Frameworks for Problem-based Learning in K-12 |
| Investigator: | Laurie Campbell, Co-Investigator: Samantha Heller |
| IRB ID: | STUDY00000735 |
| Funding: | None |
| Grant ID: | None |
| Documents Reviewed: | • Contact Card left after interview, Category: Other;<br>• Lines of Question for Teacher Interviews, Category: Other;<br>• Parents Explanation of Research, Category: Consent Form;<br>• Protocol, Category: IRB Protocol;<br>• Teacher Explanation of Research, Category: Consent Form; |

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made, and there are questions about whether these changes affect the exempt status of the human research, please submit a modification request to the IRB. Guidance on submitting Modifications and Administrative Check-in are detailed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Gillian Bernal

Gillian Bernal
Designated Reviewer

Page 1 of 1

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