ABSTRACT

SWANSON HOYLE, KYLIE JAYNE. Investigating the Interactions, Beliefs, and Practices of Teacher-Coach Teams in a STEM After-School Setting. (Under the direction of Dr. Margaret R. Blanchard.)

After-school programs, such as a STEM Career Club, can promote student interest, engagement, and awareness of STEM majors and fields, as well as encourage teachers to become more knowledgeable and competent in STEM areas. In this dissertation study, two schools were selected from a larger NSF-funded project to participate in this study. Teacher-Coaches (T-Coaches) from two rural middle schools in the southeastern United States (U.S.) participated in teacher professional development (TPD) sessions and Professional Learning Community (PLC) meetings to prepare them to lead an after-school STEM Club. The Community of Practice (CoP) framework and Social Cognitive Theory are employed to investigate underlying factors that contribute to teacher interactions and preparations, and differing STEM program outcomes. Data from the Dimensions of Success (DoS) observation tool, the teacher belief interview (TBI), T-Coach participation and attendance at TPD, attendance and audio recordings from PLC meetings, and T-Coach card sorts were analyzed over approximately 6 meetings for 5 months.

Findings are presented in two chapters. In Chapter Four, a comparative case study of the interactions of the teachers at two participating middle schools is analyzed. Results indicate that for each case, the club's T-Coaches interacted positively to prepare for club meetings and have a well-functioning CoP within their PLC. The first case (Northern Middle School) interacted in ways that aligned with the CoP framework (enterprise and repertoire), which led them to achieve, on average, desirable ratings on 7 of the 12 DoS dimensions. However, the other case (Southern Middle School), the T-Coaches interacted in ways that
demonstrated more equal levels of enterprise, mutuality, and repertoire; this PLC had higher DoS ratings during the STEM Clubs in all dimensions (11/12 met desirable ratings). These findings suggest that high levels of all of the social learning characteristics within PLCs can support more exemplary STEM Club implementation.

In Chapter Five, results from the two schools of teachers’ beliefs and practices indicate that for STEM program success, the whole of the team is better than the sum of its parts. Since individuals' values on each team aligned with different DoS dimensions, it was more likely that each dimension would be represented during STEM Clubs. Findings suggest that it was necessary for two T-Coaches who valued a certain dimension to ensure a DoS dimension would be met on the DoS rating. However, it was not sufficient that T-Coaches only valued a certain dimension. The dimension was not met if the T-Coaches did not have the training and preparation to meaningfully act on their beliefs. Informed by factors from Bandura’s Social Cognitive Theory, these T-Coaches carried out different behaviors at the STEM Clubs depending on their personal beliefs and values, and the environment. Five TPD participation scenarios, ranging from full to no TPD preparation, identified from the findings seemed to predict the quality of the STEM Club, based on DoS scores.

The following conclusions can be drawn: 1) Professional learning community meetings aided in the development of T-Coaches’ community of practice and preparation for STEM clubs; 2) A CoP with high levels of all of the social learning characteristics (enterprise, mutuality, and repertoire) led to more desirable club outcomes than a team with lower levels in any of these areas; 3) At least two people who have developed the content knowledge and relevant skills and who value club success were needed at club meetings to ensure STEM Club success; 4) Teacher-Coaches became more prepared to lead successful
STEM Clubs through engaged attendance at TPD and PLC meetings; 5) Interdisciplinary teacher teams, including non-STEM teachers, can successfully lead STEM clubs if the individuals are able to learn the content/skills.
Investigating the Interactions, Beliefs, and Practices of Teacher-Coach Teams in a STEM After-School Setting

by
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BIOGRAPHY

I was born and raised in Pennsylvania, attended K-12 public school and spent four years earning my undergraduate degree in biology at Pennsylvania State University. When I started my biology degree, my initial goal was to attend medical school. However, the thought of continuing school for eight more years felt really daunting (funny, right?) and the idea of working in the medical field didn’t exactly make my heart sing. One day, a friend of mine asked what I would do with my life if money didn't matter. I said, "I would teach science and coach track" and she said, "Then do that." Following that interaction, I took my love for coaching kids and my passion for science to fuel my decision to pursue a career in education. Having two sisters already living in North Carolina, and wanting to leave the cold of the north, I moved to Charlotte, NC.

I was accepted into the teacher certification program at the University of North Carolina at Charlotte and began taking courses immediately. My family urged me to take advantage of North Carolina's lateral entry program, which allowed me to have the privilege of working at Jay M. Robinson Middle School for three years while pursuing my teaching certification. During my time at Jay M. Robinson I coached track and field and Science Olympiad, was department chair during my final year, and had the opportunity to participate in a research study that piloted a new science curriculum called "Project Based Inquiry Science" from It's About Time publishing. This strategy for teaching science changed my entire view of science education and ignited my desire to inspire other educators to teach science in this fashion.

After completing my teaching certification, I continued at UNC Charlotte to earn my Masters in the Art of Teaching degree with a focus on middle grades science education.
Once I finished my coursework for my MAT, I began applying to doctoral programs. I was accepted at North Carolina State University and gladly signed on for an assistantship as a teaching assistant in the College of Education. My husband and I moved to Raleigh, NC in the fall of 2014 to start this crazy, full-time journey at NC State in the Science Education Ph.D. program.
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I would also like to thank the wonderful people at the Science House at NC State, Dr. Jason Painter and Scott Ragan, for providing me with a home base for the past two years. I would also like to acknowledge the other faculty members working on the STEM Career Club project, Braska Williams Jr. and Dr. DeLeon Gray, for their continued support. Someone very close to me, the postdoctoral fellow on the project, Dr. Kristie Gutierrez deserves a very large thank you! She has been such a wonderful friend, confidant, sounding board, mentor, big sister, flight turbulence fright suppressor, life coach #2, adventure companion, proofreader, DoS evaluator, and teacher interviewer. Without Kristie, I think I would have lost my mind a time or two during this past year of the dissertation. I cannot wait to go to Ireland with her and Meg and be able to celebrate (and present at ESERA). I really look forward to working with Kristie in the future and spending time with her at conferences!
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I want to take a moment to also thank the teachers who were part of the STEM Career Clubs project this year. Not only did they allow me into their team, they made me feel as if I was part of it. The relationships created with these individuals will make leaving NC State even harder. They are some of the most dedicated, thoughtful, and caring educators I have ever met. They work in some of the toughest areas and still manage to make a difference in students' lives. I wish them the best of luck in the future and in the continuation of STEM Career Clubs!

Throughout this process I had the opportunity to work with an amazing dissertation committee who have all helped me grow as a scholar and a professional. I want to thank Dr. Jason Painter again for his guidance, support, comedic relief, and help to create a manuscript for publication based off of my minor exam work. I also would like to thank Dr. Sarah Carrier, who was also my initial advisor, for her guidance and support and providing the opportunity to work on data analysis and research manuscript preparation. Additionally, I would like to thank Dr. Soonhye Park for her guidance from my dissertation proposal into the research phase and I greatly appreciate the valuable feedback she has provided. I would like to thank each of my committee members for their unwavering support and flexibility through this demanding process.
I would also like to mention some very important people who entered this journey at the same time I did and with whom I have gotten the chance to become closer to throughout the past three years. I want to thank my good friend, Brandon Alonzo Alexander, for always believing in me and reminding me why I deserve to be here. His friendship and continued support have helped me make it to the finish line and I have been inspired by his own personal perseverance. I want to recognize Emily Cayton, who has become a life-long friend. Thank you for answering the phone and talking through whatever was on my mind. You have made the loneliness of a Ph.D. feel less daunting. Please remember to call me when you need that person as you complete your Ph.D. this coming year! Osman Aksit has been a friend and positive influence throughout the program. He has also been a friendly smile and support system when I wasn't sure how I would get through juggling coursework. A thank you to Katherine Chesnutt for helping keep me on track and focused. You have been essential to my success of completing this program in three years.

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CHAPTER ONE

Introduction

Since 2006, a national push for Science, Technology, Engineering, and Mathematics (STEM) programs and initiatives, and the acronym "STEM" began appearing in headlines (Boelter, Link, Perry, & Leukefeld, 2015). These efforts were initiated to allow the U.S. to remain competitive in STEM fields in both the developing world and U.S. markets. Numerous reports document a deficiency of young U.S. students who choose to pursue STEM majors in college; as a result, there is a shortage of individuals to fill STEM career positions (Boelter et al., 2015; Cannady, Greenwald, & Harris, 2014; Carnevale, Smith, & Melton, 2011; Franco, Patel, & Lindsey, 2012; Holdren, Lander, & Varmus, 2010). In particular, there is a shortage of Hispanics, African Americans, and females pursuing STEM majors and careers (Heaverlo, 2011; Holdren et al., 2010; Nikischer, 2013). Kier (2013) and Walton (2015) both suggest that students need to be aware of the education requirements for STEM careers, as well as the numerous career paths available in STEM. STEM interest has been documented as most vulnerable to decline during middle school years, indicating that encouragement during those crucial years could have a dramatic impact on students' enthusiasm and interest (Business-Higher Education Forum (BHEF), 2012).

STEM programs can be meaningful to encourage K-12 students' engagement and interest in STEM fields and careers. Some schools have stimulated student interest in STEM through STEM Clubs, Robotics clubs, Engineering clubs, or clubs in closely related subjects (ChanJin Chung, Cartwright, & Cole, 2014; Dabney et al., 2012; Dabney, Tai, & Scott, 2015; Kong, Dabney, & Tai, 2014). However, few researchers have studied the efforts to plan and prepare for these STEM programs as individuals or teams (Franco et al., 2012; Nikischer,
2013; Schneider, 2012; Walton, 2015; Ward, 2015). To date, no research has been conducted on how the beliefs of individuals implementing STEM programs compare to or influence observed practices.

*PLC Meetings*

Previous studies that suggest that the implementation of a Professional Learning Community (PLC) can create positive results for new initiatives (Park & So, 2014; Ronfeldt, Farmer, McQueen, & Grissom, 2015) and provide benefits for teachers and students (Hardinger, 2013; Owen, 2015; Ronfeldt et al., 2015). School implementation of a PLC has also been linked to an increase in the number of students who reach achievement goals (Hardinger, 2013; Owen, 2015; Ronfeldt et al., 2015). Hardinger (2013) used the *School Professional Staff as a Learning Community Questionnaire* to assess 65 principals' perceptions of their school's PLC implementation. After analyzing and interpreting the participating schools’ academic achievement, graduation rates, and school demographics, the author found a statistically significant positive relationship between the degree of PLC implementation (i.e., a shared mission, vision, values, belief in the PLC purpose, and group collaboration to ensure that their common goals are met) and academic achievement and graduation rates.

However, this dissertation study investigated the role of a Community of Practice (CoP) within a PLC in the context of an informal setting (i.e., after-school STEM Club), which has yet to be investigated. Drawing on previous literature, enacting a PLC can advance teachers' knowledge, efficacy, and beliefs (Miranda & Damico, 2015; Moirao, Morris, Klein, & Jackson, 2012; Owen, 2015; Park & So, 2014). Miranda and Damico (2015) created a summer teacher professional development (TPD) that required 14 high
school science teachers to meet as a PLC monthly during the school year. Pre-participation essays, discussion board posts, lesson observations (RTOP), and teacher questionnaires revealed that teachers' beliefs and knowledge of inquiry teaching developed further with the PLC extension. The PLC helped the teachers further develop their understanding of reform-based practices, modify their beliefs about teaching and learning, and change their observed practices as a result of support and suggestions from other teachers (Miranda & Damico, 2015).

In addition, research on effective PLCs have reported that encouraging more innovative teaching practices and communication between teachers positively impacts outcomes (Owen, 2015; Park & So, 2014; Vescio, Ross, & Adams, 2008). Previous research on PLCs also provides evidence that PLCs have a higher success rate when interpersonal relationships are strong (Robertson & Jones, 2013). Mizzi (2013) reported that PLCs are most effective when its members agree on goals of the PLC, such as norms and roles, adequate time is provided, and there is continual support from administration or the research team. Robertson and Jones (2013) also documented that teachers in PLCs had significant concerns related to interpersonal relationships and communication styles within the group, and many talked about team functioning as key to their PLC work.

Teacher Beliefs

Previous studies suggest that the beliefs teachers hold can influence their practices (Addy & Blanchard, 2010; Blanchard, LePrevost, Tolin, & Gutierrez, 2016; Blanchard, Southerland, & Granger, 2009; Capps & Crawford, 2013; De Vries, Jansen, & van de Grift, 2013; Kunter et al., 2013; Lotter, Rushton, & Singer, 2013; Lumpe, Czerniak, Haney, & Beltyukova, 2012; Southerland, Sowell, Blanchard, & Granger, 2011; Wallace & Kang,
It is important to understand teacher's beliefs as their ideas about learning and teaching can influence outcomes (Kunter et al., 2013). Kunter et al. (2013) analyzed 181 secondary math teacher's teacher belief interview (TBI) scores compared to student content gains. The researchers found that teachers who endorsed constructivist beliefs (indicated from student questionnaire ratings) showed higher student math achievement gains on state exams. Similarly, Lumpe, Czerniak, Haney, and Beltyukova (2012) investigated the beliefs of 450 elementary teachers' that participated in a long-term, intense (over 100 hours annually), science professional development program using the Science Teaching Efficacy Beliefs Inventory (STEBI) and the Context Beliefs About Teaching Science (CBATS). The authors found that beliefs (higher STEBI and CBATS outcomes) and participation in TPD were significantly predictive of students’ state science achievement test scores.

Teacher beliefs can also affect student achievement (Kunter et al., 2013; Lumpe et al., 2012). Beliefs teachers hold can also change how receptive they are to Teacher Professional Development (TPD) (Barak & Shakhman, 2008; Berg, 2012; Southerland et al., 2011). Prior studies have provided evidence that teacher beliefs can also influence how willing an individual is to adopt new teaching methods (Blanchard et al., 2009). Additionally, teacher beliefs have been associated with how teachers decide how to teach (e.g. low inquiry beliefs, low inquiry observed in lessons) (Capps & Crawford, 2013; Lotter et al., 2013; Wallace & Kang, 2004).

Research suggests that it is possible to positively influence teacher beliefs through TPD (Blanchard, LePrevost, Tolin, & Gutierrez, 2016; De Vries, Jansen, & van de Grift, 2013). Although some research would suggest that even if teachers hold positive beliefs toward inquiry based, collaborative, student-centered teaching, this style of teaching is not
consistently seen in their observed practices (Addy & Blanchard, 2010; Chaumklang, 2013).

Teachers' beliefs can be influenced by a number of factors such as classroom expectations, curriculum reform, high-stakes testing, and school environment. Therefore, it is essential to know the challenges teachers perceive before TPD (Driel, Beijaard, & Verloop, 2001; Zhang & Liu, 2014).

*Theoretical Framework*

*Community of Practice*

Wenger (1998) defines Community of Practice (CoP) as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (p. 1). These communities can exist in various contexts: a high school soccer team, a group of software engineers, or a group of teachers who meet regularly to plan and prepare for student STEM Club meetings. However, not everything referred to as a community, such as a town or city, is a CoP. Snyder and Wenger (2010), Wenger (1998; 2000), and Wenger and Snyder (2000) describe three characteristics that define a CoP: domain, community, and practice. The combination of these three characteristics - domain, community, and practice - defines a Community of Practice (CoP). The purpose of a CoP is to develop members' abilities and to share and build knowledge. Within a CoP, individuals who belong are members who select themselves. The commitment, passion, and identification with the group's expertise are what hold the CoP together. The CoP will continue as long as there is a shared interest in maintaining the group among members (Wenger & Snyder, 2000).
Social Cognitive Theory

In 1986, Albert Bandura developed Social Cognitive Theory (SCT) to include cognition as a factor affecting human behavior. Through SCT, Bandura suggests that cognitive processes are a transitional determinant of human behavior and have a large influence on the environments that impact behavior. The concept of including cognition had not been included in previous social learning theories.

Reciprocal Determinism

Bandura (1986) described the interactions between personal, behavioral, and environmental factors as reciprocal determinism (see Figure 1.2). Personal factors include cognition, attitudes, and beliefs. Thus, SCT provides a framework crucial to understanding the variables in the present study of Teacher-Coach (T-Coach) beliefs and behavior. Bandura's model suggests that humans' beliefs will influence behavior (e.g., T-Coach practices at STEM Club meetings) and that behavior will regulate human beliefs. Environmental factors (e.g., attendance at TPD or PLC meeting) are influenced by the humans' beliefs and values. Additionally, environmental factors influence individual's behavior and vice versa. Bandura (1978) also posits that it is more meaningful to predict an individual's behavior through their beliefs than from the outcomes of their actions. Although it is possible for all factors to act simultaneously, the activation of these factors occurs independently in most instances (Bandura, 1986). Bandura also explains that these factors are not equal in power but are in constant flux depending on the activity, the individual, and the circumstance.
Dimensions of Success Observation Tool

The extent to which an after-school program is beneficial to students depends upon the quality of the program (Mahoney, Levine, & Hinga, 2010). Determining the level of quality of STEM programs has been difficult, in part due to the lack of evaluation tools for Out of School Time (OST) programs, particularly for STEM programs (Papazian, Noam, Shah, & Rufo-McCormick, 2013). The Dimensions of Success (DoS) observation tool was created to address this issue. The PEAR Institute created the tool in 2010, based on the evaluation framework designed by the National Science Foundation (NSF) and the National Research Council (NRC).

The DoS tool is used to analyze twelve indicators of quality in STEM programs in out-of-school time (Martinez, Linkow, & Velez, 2014). The twelve DoS dimensions are categorized into four domains: 1) Features of the learning environment (Organization, Materials & Space Utilization); 2) Activity engagement (Participation, Purposeful Activities, and Engagement with STEM); 3) STEM knowledge and practices (STEM Content Learning, Inquiry, Reflection); and 4) Youth development in STEM (Relationship, Relevance, Youth Voice). Collectively, the twelve dimensions are intended to capture key factors that constitute quality out-of-school STEM activities.

Purpose Statement

The purpose of this study was to assess the ways in which two teams of T-Coaches work together and collaborate within a PLC (as a CoP) to facilitate successful STEM after-school clubs. There are numerous studies that suggest that the implementation of PLCs within the traditional school day create positive results for new initiatives (Park & So, 2014; Ronfeldt et al., 2015) and for teachers and students (Hardinger, 2013; Owen, 2015; Ronfeldt
et al., 2015). However, this study investigated the role of the PLC (CoP) in the context of an informal setting (i.e., after-school STEM Club), of which there are no published texts. Investigating T-Coach interactions can provide insight into how collaborative teams work with one another to prepare and achieve a common goal. Analyzing what types of interactions, as identified by CoP framework, leads to more favorable club outcomes and can also be meaningful for after-school literature. The result from this research informs educational institutions, educational researchers, and school systems on how to increase teacher team productivity through encouraging certain interaction types.

This study also assesses whether T-Coach beliefs are or are not associated with their observed practices. Previous literature also suggests that teachers' beliefs and values shape their practice (Capps & Crawford, 2013; Lotter et al., 2013; Wallace & Kang, 2004). However, this study investigated beliefs of leaders compared to practices in the context of an informal setting (i.e., after-school STEM Club), of which there are no published texts. Investigating club T-Coach beliefs can provide insight into how collaborative teams decide how to implement a STEM Club and which aspects have higher priority. Analyzing what beliefs lead to more favorable club outcomes can also be meaningful for after-school literature. The results from this research can inform educational institutions, educational researchers, and school systems when approaching after-school program facilitation. This research informs other educational teams as more frequently, classroom teachers are expected to work across all grade levels to collaborate and produce expected outcomes for students.
Research Questions

In order to address the gap in the literature related to teachers' planning, working relationships, and beliefs and practices in after-school STEM programs, this study investigates Teacher-Coaches working in PLCs to prepare for and carry out after-school STEM Clubs at two rural, high poverty middle school through a Community of Practice framework (Wenger, 1998), Social Cognitive Theory framework (Bandura, 1986), and employing the Dimensions of Success observation tool (Papazian et al., 2013). The research questions guiding this study are:

1. How do teachers interact and prepare for STEM Clubs during Teacher-Coach PLC meetings?
2. What tasks did Teacher-Coaches complete during PLC meetings and preparations at two different middle schools compare?
3. Are there differences in STEM Club outcomes for the two clubs, and how do these relate to interactions during Teacher-Coach PLCs?
4. What are the strengths and areas for improvement of the STEM Career Club meetings (using the DoS instrument)?
5. Which constructs of the Dimensions of Success instrument do Teacher-Coaches believe are most important for productive STEM Club meetings?
6. In what ways do the beliefs of STEM Club Teacher-Coaches at two different middle schools correspond to and differ from the DoS ratings of their STEM Club meetings?
Summary

In this chapter, T-Coach collaboration, beliefs, and practices were introduced as the topic of study, as well as the importance of the study for out-of-school contexts and teacher teams. The theoretical frameworks, the Community of Practice and Social Cognitive Theory, as well as the Dimensions of Success Rubric, were introduced. Chapter two includes an extensive review of the literature. Chapter Three details the qualitative methods that were used to collect and analyze the data collected. Chapter Four and Five are two findings chapters. Chapter Six discusses the findings and situates them within the literature. Chapter Seven synthesizes the conclusions of the two Findings chapter and implications for teacher team collaboration and practices in informal and formal contexts, as well as suggestions for future research.
CHAPTER TWO
Literature Review

Professional Learning Communities

A Professional Learning Community (PLC) is a group of individuals who work as a team and do such things as: strive to change teacher beliefs and practices, take part in collaborative work over an extended timeline, develop shared beliefs and a shared vision, carry out relevant practical activities, use an inquiry approach and learning focus, and guard against insularity (Stoll, Bolam, McMahon, Wallace, & Thomas, 2006; Vescio et al., 2008). Initiating this type of collaborative group can help launch a new program (Park & So, 2014; Ronfeldt et al., 2015) and increase outcomes for teachers and students (Hardinger, 2013; Owen, 2015; Ronfeldt et al., 2015). PLCs can also be valuable when teachers are team teaching (Mizzi, 2013). Although PLCs are commonly used in education, there were no studies found on PLCs in out-of-school or after-school settings.

New Initiatives

Designated team planning time, such as in a PLC, can aid in the success of new initiatives (Park & So, 2014; Ronfeldt, Farmer, McQueen, & Grissom, 2015). Park and So (2014) investigated the perspectives of three South Korean science teachers on the implementation of a PLC in their school, through interviews. The teachers reported that these experiences enhanced their teaching quality, communication, and enriched their understanding of their teaching practice. The participants believed the PLC allowed them to freely discuss ideas, challenge others’ and their own way of thinking, create a culture of peer learning, and embody an inquiry stance toward teaching.
Benefits for Teachers and Students

School implementation of a PLC has also been linked to an increase in the number of students who reach achievement goals (Hardinger, 2013; Owen, 2015; Ronfeldt et al., 2015). Hardinger (2013) used the School Professional Staff as a Learning Community Questionnaire to assess 65 principals' perceptions of their school's PLC implementation. After analyzing and interpreting the participating schools’ academic achievement, graduation rates, and school demographics, the author found a statistically significant positive relationship between the degree of PLC implementation (i.e., a shared mission, vision, values, belief in the PLC purpose, and group collaboration to ensure that their common goals are met) and academic achievement and graduation rates.

Ronfeldt et al. (2015) found similar results. They conducted a study that surveyed administrative data on over 9,000 teachers in 336 Miami-Dade County public schools, over two years, to investigate the types of collaborations that existed in instructional teams and if these collaborations had an impact on student achievement. The researchers found that the quality of the collaboration (i.e., teachers' perception of how helpful and extensive the collaboration is) is related to student achievement. Ronfeldt et al. also found that better quality collaboration in PLCs enhances teachers' classroom performance.

Teachers also have reported increased learning outcomes for students as a result of PLCs, not only in terms of achievement, but also enhanced social skills, emotional aspects, independence, and creativity. Owen (2015) investigated how PLCs operate and how the use of PLCs affects student learning, based on interviews with teachers and student-learning outcomes in three different schools (two secondary and one primary). The data revealed that the most influential part of the PLC was the teachers learning within the PLC, which was
attributed to co-planning, co-teaching, and co-assessment. Furthermore, the evidence showed that PLCs support changes in teacher practices relevant to innovative contexts (i.e., student centered, reform-based) and increased learning outcomes for students not only in terms of achievement but also social skills, emotional aspects, independence, and creativity (Owen, 2015).

Taking part in a PLC can also advance the teacher's knowledge, efficacy, and beliefs (Miranda & Damico, 2015; Moirao et al., 2012; Owen, 2015; Park & So, 2014). Miranda and Damico (2015) created a summer teacher professional development (TPD) that required 14 high school science teachers to meet as a PLC monthly during the school year. Pre-participation essays, discussion board posts, lesson observations (RTOP), and teacher questionnaires revealed that teachers' beliefs and knowledge of inquiry teaching developed further with the PLC extension. The PLC helped the teachers further develop their understanding of reform-based practices, modify their beliefs about teaching and learning, and change their observed practices as a result of support and suggestions from other teachers (Miranda & Damico, 2015).

Effective PLCs have been reported to encourage more innovative teaching practices and mutual communication (Owen, 2015; Park & So, 2014; Vescio et al., 2008). A synthesis report of 74 studies by Fulton and Britton (2011) found that STEM teaching is more effective and student achievement increases when teachers come together to develop strong PLCs in their schools (i.e., PLCs with strong leadership support, time, collective responsibility, good facilitation, and trust). In Fulton and Britton's report, STEM PLCs had positive effects on teachers' instructional practices, by advancing teachers’ content preparedness and attitudes...
toward teaching methods in addition to increased science and mathematics achievement outcomes for students.

Similarly, using The Science Professional Learning Communities Survey (N= 65) and interviews (n= 16), Robertson and Jones (2013) found that most teachers in PLCs reported sharing ideas with other teachers on how to improve students’ science standardized test scores through the process of looking at state and national standards for a particular science topic (such as forces and motion) together. The teachers believed that the PLCs positively impacted their science assessment practices as well as their lesson planning, though discussions on strategies for inquiry teaching (i.e., sharing lab materials, books, and other resources for teaching specific science topics).

Benefits when Team Teaching

PLCs are crucial when team teaching, or when one member is outside of his or her content area - as time is needed for training and planning. Mizzi (2013) reviewed studies that investigated the challenges teachers face when teaching outside of their science specialism. Challenges identified include: lack of confidence, preparing lesson plans, choosing or devising activities and analogies to aid students’ learning, answering students’ questions, setting up laboratory experiments, linking and applying various concepts and principles to everyday life situations, and generating students’ interest and passion for the science area. Mizzi reported that these challenges are due to limited subject matter knowledge (SMK, an individual's content expertise) in a particular science area. Mizzi claimed that SMK influences the development of the teachers’ pedagogical content knowledge (PCK, an individual's expertise on how to teach content). He reviewed some of the methods teachers have developed to handle these challenges, such as reading subject textbooks, obtaining
resource packs and schemes of work, and seeking help and advice from school colleagues who are subject specialists. Teachers can still excel in teaching outside of their expertise, if they receive or seek out support to do so.

Success in PLCs

Mizzi (2013) reported that PLCs are most effective when its members agree on goals of the PLC, such as norms and roles, adequate time is provided, and there is continual support from administration or the research team. Robertson and Jones (2013) also documented that teachers in PLCs had significant concerns related to interpersonal relationships and communication styles within the group, and many talked about team functioning as key to their PLC work. About one-third of teachers reported that their group functioned well and that the science PLC helped them “feel more like a team instead of just a bunch of teachers” (p. 1768). However, most of the teachers (63%) talked about significant problems with interpersonal relationships and communication styles within the group. Two teachers noted, “PLCs can really work as long as you have cooperative people” and “they are not effective when you don’t get along” (p. 1768). These results show that dynamics between PLC members are important considerations when implementing a PLC.

These studies show that organizing a PLC can provide support for new initiatives and can result in benefits for teachers (innovation, knowledge, and communication) (e.g., Park & So, 2014; Ronfeldt et al., 2015), and students (achievement and skills) (e.g., Hardinger, 2013; Owen, 2015; Ronfeldt et al., 2015). A PLC is also valuable when one or more of the teachers in the group are out of their content expertise (e.g., Mizzi, 2013). A PLC could be an innovative approach to having teachers run an after-school STEM program at a school and
asking teachers to collaborate and work together to facilitate the program at their schools for students.

Teacher Beliefs

It is important to consider teachers' beliefs when attempting to initiate a new program, as beliefs can influence student and program outcomes and influence teachers' practices (Kunter et al., 2013; Lumpe et al., 2012). There are also challenges to overcome when trying to influence teachers' beliefs (e.g., Blanchard, Southerland, & Granger, 2009; Zhang & Liu, 2014). In some cases, teachers may change their beliefs through teacher professional development (TPD), yet there is a disconnect between those beliefs and their observed practices (e.g., Capps & Crawford, 2013).

Beliefs Influence Outcomes

It is important to understand teacher's beliefs as their ideas about learning and teaching can influence outcomes (Kunter et al., 2013). Kunter et al. (2013) analyzed 181 secondary math teacher's teacher belief interview (TBI) scores compared to student content gains. The researchers found that teachers who endorsed constructivist beliefs (indicated from student questionnaire ratings) showed higher student math achievement gains on state exams. Similarly, Lumpe, Czerniak, Haney, and Beltyukova (2012) investigated the beliefs of 450 elementary teachers' that participated in a long-term, intense (over 100 hours annually), science professional development program using the Science Teaching Efficacy Beliefs Inventory (STEBI) and the Context Beliefs About Teaching Science (CBATS). The authors found that beliefs (higher STEBI and CBATS outcomes) and participation in TPD were significantly predictive of students’ state science achievement test scores.
Beliefs Influence Practice

Additionally, teacher beliefs have been associated with how teachers decide to teach (i.e., novice inquiry beliefs, low inquiry observed in lessons) (Capps & Crawford, 2013; Lotter et al., 2013; Wallace & Kang, 2004). Capps et al. (2013) studied 26, fifth through ninth grade teachers' views and practice of inquiry and their reform-based efforts. Through lesson descriptions, classroom observations, videotape data, questionnaires and interviews, the researchers found these teachers had limited views of inquiry. They also found that this related to directly to their classroom instruction, which used limited inquiry methods. These findings indicate that teachers may support from outside sources to shift these ideas.

Beliefs can Change with TPD

In their study with 20 middle school teachers, Blanchard, LePrevost, Tolin, and Gutierrez (2016) used the TBI, STEBI, and reform-based teaching observation protocol (RTOP), and found that teacher beliefs about teaching and comfort with technology in the classroom changed significantly over the course of the three-year TPD. In this study, all 20 teachers used technology in their classrooms, some in ways that transformed their roles in the classroom, but majority did so in ways that improved the efficiency and effectiveness of their teaching. Similarly, De Vries at al. (2013) surveyed 260 teacher participants using five constructs under the umbrella of continuing professional development (CPD): activities, updating practices, reflection, collaboration, and their student- and subject matter-oriented beliefs. The researchers found a positive correlation between participating in Continuing Professional Development (CPD) and student oriented beliefs.
Beliefs may differ from Practice

Although some research suggests that teachers’ may hold positive beliefs about inquiry-based, collaborative, student centered teaching, these may not correspond to their observed actions in the classroom (Addy & Blanchard, 2010; Chaumklang, 2013). Addy and Blanchard (2010) investigated the reform-based teaching beliefs of eight Graduate Teaching Assistants (GTAs) using the Teacher Belief Interview (TBI), compared to their observed teaching practices (using the Reform-based Teacher Observation Protocol (RTOP)). The researchers found that although the GTAs held moderately reform-minded beliefs, their instruction was fairly traditional. Chaumklang (2013) also found with four Thai high school physics teachers that although the teachers’ beliefs (described during interviews) about what ‘student centered’ means were consistent with reform efforts, their classroom practices (during class observations) did not reflect student-centered teaching.

Teachers' beliefs can be influenced by a number of factors, such as classroom expectations, curriculum reform, high-stakes testing, and the school environment; therefore, it is good to know what challenges teachers perceive before teacher professional development (Zhang & Liu, 2014).

Challenges Associated with Beliefs

An article by Southerland et al. (2011) explains that there are internal factors that can change how receptive a person is to professional development. The authors explain that an individual's pedagogical discontentment and level of self-efficacy have a major influence over what they will adopt from professional development. Similarly, Berg's (2012) study on elementary teachers' dilemmas after TPD found that one’s career stage and supportive coaching supported teachers' ability to teach science in more reform-based ways. Blanchard
et al. (2009) investigated four secondary science teachers after a six-week TPD based in an authentic research setting. The researchers used questionnaires, interviews, classroom recordings and the Science Teacher Inquiry Rubric (STIR) instrument to analyze what beliefs the teachers originally held before the TPD and how the teachers enacted planned lesson following the TPD. The researchers found that teachers who had more sophisticated understandings of educational theory and their understanding of inquiry-based instruction were more able to adopt the inquiry methods and implement them in their classrooms. Therefore, awareness of teachers’ beliefs is important when planning TPD.

The impact of teachers' beliefs on their practices and how this can affect outcomes for students and programs is important to address when launching a STEM after-school program. These beliefs can change how the teachers implement to program or how open-minded they are to the student-centered, informal environment. The teachers' beliefs can also maintain ideals the program hopes to instill however; they may not carry through with these beliefs in their observed practices.

**Dimensions of Success Observation Tool**

The extent to which an after-school program is beneficial to students depends upon the quality of the program (Mahoney et al., 2010). Determining the level of quality of STEM programs has been difficult, in part due to the lack of evaluation tools for Out of School Time (OST) programs, particularly for STEM programs (Papazian et al., 2013). The Dimensions of Success (DoS) observation tool was created to address this issue. The PEAR Institute created the tool in 2010, based on the evaluation framework designed by the National Science Foundation and the National Research Council (NRC). The NSF framework describes five impact categories (Friedman, 2008):
1. Awareness, knowledge, or understanding of STEM concepts, processes, or careers;

2. Engagement or interest in STEM concepts, processes, or careers;

3. Attitude toward STEM-related topics or capabilities;

4. Behaviors related to STEM concepts, processes, or careers;

5. Skills based on STEM concepts, processes, or careers (p. 11).

The NRC framework features the significance of students’ interest and excitement, investigate and examine questions, reflect and practice scientific language and tools, their ability to use models and provide justifications; and their ability to identify as individuals who can learn, use, and contribute to science (Bell et al., 2009). The DoS tool was validated in 2010 by through collaboration with Educational Testing Services (ETS), with funding from the National Science Foundation (NSF). A team of DoS trained researchers observed over 300 STEM programs across seven states to ensure validity. The creators piloted the tool in multiple settings, and it is designed to assist researchers, practitioners, funding agencies, and other stakeholders to track the quality of STEM learning opportunities and to pinpoint program strengths and weaknesses (Papazian et al., 2013). The final DoS tool is used to analyze twelve indicators of quality in STEM programs in out-of-school time (Martinez et al., 2014). The twelve DoS dimensions are categorized into four domains: 1) Features of the learning environment (Organization, Materials & Space Utilization); 2) Activity engagement (Participation, Purposeful Activities, and Engagement with STEM); 3) STEM knowledge and practices (STEM Content Learning, Inquiry, Reflection); and 4) Youth development in STEM (Relationship, Relevance, Youth Voice). Collectively, the twelve dimensions are intended to capture key factors that make quality out-of-school STEM activities (Figure 2.1).
To date, the research associated with DoS has included STEM program evaluation and reports given to leaders to learn what areas they were strong in and program dimensions that needed improvement (Dahlgren & Noam, 2009; Martinez et al., 2014; Papazian et al., 2013). Another study by Papazian et al. (2013) provided DoS training for STEM OST program leaders and evaluated their program before and after. They found significant gains in the program results after providing DoS training for the participants.

The DoS observation tool Papazian et al. (2013) seems to be a promising way to evaluate STEM program success, if the goals of the program match those reform-based practices recommended by the model. To date, the DoS observation tool has not been used in settings outside of STEM Clubs/OST meetings. In this study, it will be used as an analytical tool during STEM Club meetings.
Theoretical Frameworks

*Community of Practice*

Wenger (1998) defines Community of Practice (CoP) as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (p. 1). These communities can exist in various contexts: a high school soccer team, a group of software engineers, or a group of teachers who meet regularly to plan and prepare for student STEM Club meetings. However, not everything referred to as a community, such as a town or city, is a CoP. Snyder and Wenger (2010), Wenger (1998; 2000), and Wenger and Snyder (2000) describe three characteristics that define a CoP: domain, community, and practice (see Figure 2.2).

*Figure 2.2. Community of Practice framework.*

**Domain.** A CoP is centered on a certain 'domain,' which helps the community create an identity related to what is important to them. Membership in the CoP involves a commitment to and passion for the domain. Snyder and Wenger (2010) explain, "Members'
passion for a domain is not an abstract, disinterested experience. It is often a deep part of their personal identity and the means to express what their life's work is about" (p. 110). The passion and sense of identity results in a shared competence that differentiates members from non-members. A CoP of chess players may have expert game moves and advanced game knowledge. Although people outside of the community may not appreciate its worth, members value their shared competence and learn from one another.

Community. While striving to attain their objectives in their domain, members engage in activities and discussions together. During these interactions, they help one another and share information, building relationships. These relationships allow members to openly share and learn from one another. Tallman and Feldman (2016) explain, "Community fosters interactions and relationships based on mutual respect and trust. It encourages a willingness to share ideas, expose one's ignorance, ask difficult questions, and listen carefully" (p. 330). Even if individuals function together as a community, such as all of the students in the sixth grade, the group is not a CoP unless they are interacting to learn from one another and share information. These interactions are essential to the community, even if the practice is performed individually. For example, teachers in a Professional Learning Community (PLC) will collaborate within a setting (domain) and form a community with one another, but they then practice their craft (teaching) in their individual classrooms.

Practice. Through their community, members build a repertoire of resources or shared practices that they continually improve and maintain including "frameworks, ideas, tools, information, styles, languages, stories, and documents that community members share" (Wenger, McDermott, & Snyder 2001, p. 29). Building this repertoire takes time and continual interaction, and the process requires reflection on one’s practices to identify
strengths and weaknesses. An example of a shared resource would be when teachers in a PLC create lesson plans collaboratively in Google Drive™ to use in their classrooms.

The combination of these three characteristics - domain, community, and practice - defines a Community of Practice (CoP). The purpose of a CoP is to develop members' abilities and to share and build knowledge. Within a CoP, individuals who belong are members who select themselves. The commitment, passion, and identification with the group's expertise are what hold the CoP together. The CoP will continue as long as there is a shared interest in maintaining the group among members (Wenger & Snyder, 2000).

Social learning takes place in a CoP when there is enterprise, mutuality, and repertoire as referred to as 'Dimensions of Progress' (see Table 2.1) (Wenger, 2000).

*Enterprise* is the level of learning energy in the CoP (Wenger, 2000). Enterprise is the continual learning and reflection of the community and how much initiative is taken by members to ensure learning and reflection happen. A community must also show leadership in moving its development forward and preserving an essence of inquiry. Remaining open to evolving directions and opportunities is also a priority for a community, as well as individuals' addressing gaps in the community's knowledge.

*Mutuality* is the depth of social capital within the community. Social capital (networks of relationships, reciprocity, trust, and social norms) depends on the level to which members are committed to forming a community. Creating a community would involve becoming comfortable with and knowing each other well enough to interact productively. Wenger postulates that members "must trust each other, not just personally, but also in their ability to contribute to the enterprise of the community, so they feel comfortable addressing real problems together and speaking truthfully" (Wenger, 2000, p. 230).
Repertoire refers to how self-aware the community is and how committed it is to developing its practice. The concepts and language a community uses embody its history such as the tools, routines, words, stories, gestures, ways of doing things, symbols, genres, actions and concepts that the community has adopted throughout its development (Wenger, 2000). The community should reflect on its repertoire to understand its state of development and reassess previous assumptions and patterns to move forward.

Table 2.1

<table>
<thead>
<tr>
<th>Social Learning Dimensions of Progress in a Community of Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enterprise: learning energy</strong></td>
</tr>
<tr>
<td>Community takes initiative to keep learning at the center</td>
</tr>
<tr>
<td>Community continues to develop productively</td>
</tr>
<tr>
<td>Community addresses gaps in its knowledge</td>
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<tr>
<td>Community seeks learning opportunities</td>
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</tbody>
</table>

Wenger (2000) explains that the three dimensions build upon one another, "Without the learning energy of those who take initiative, the community becomes stagnant. Without strong relationships of belonging, it is torn apart. And without the ability to reflect, it becomes hostage to its own history" (p. 230).

In this study, the *domain* is the STEM Career Club project, the *community* is the group of teachers from a single school who attend TPD meetings and PLC meetings, and the *practice* is teachers carrying out the STEM Club at their schools.

**Social Cognitive Theory**

In 1986, Albert Bandura developed Social Cognitive Theory (SCT) to include cognition as a factor in effecting human behavior. Through SCT, Bandura suggests that
cognitive processes are a transitional determinant of human behavior and have a large influence on the environments that impact behavior which had not been included in previous Social Learning Theories. Bandura (1986) also described how personal, behavioral, and environmental factors interact together to reciprocally shape human behavior.

*Reciprocal Determinism*

Bandura (1978) described the interactions between personal, behavioral, and environmental factors as reciprocal determinism (see Figure 2.3). Personal factors include cognition, attitudes, and beliefs. Thus, SCT provides a framework crucial to understanding the variables in the present study of T-Coach beliefs and behavior.

![Figure 2.3. Reciprocal determinism, as described by Bandura (1986), applied to T-Coach Participants](image)

Bandura's model suggests that T-Coach beliefs will influence behavior (e.g., T-Coach practices at STEM Club meetings) and that behavior will regulate T-Coach beliefs. Environmental factors (e.g., attendance at TPD or Professional learning community (PLC) meeting) are influenced by the T-Coaches' beliefs and values. Additionally, environmental factors influence individual's behavior and vice versa. Bandura also posits that it is more
meaningful to predict an individual's behavior through their beliefs than from the outcomes of their actions. Although it is possible for all factors to act simultaneously, the activation of these factors occurs independently in most instances (Bandura, 1986). Bandura also explains that these factors are not equal in power but are in constant flux depending on the activity, the individual, and the circumstance.
CHAPTER THREE

Methods

Design

This study uses a comparative, case study design (Creswell, 2014) to investigate how Teacher-Coaches (T-Coaches) who lead after-school STEM Career Clubs interact and collaborate to prepare for student club meetings. This study also analyzes how Teacher-Coaches valued dimensions of STEM Club implementation, based on dimensions the Dimensions of Success (DoS) instrument, and how those perceptions influenced the student club meetings. T-Coach teams from two STEM clubs that were a part of a larger-scale teacher professional development (TPD) project were purposely selected as separate cases. STEM clubs at these two schools were observed, and qualitative data was gathered during T-Coaches’ PLC meetings, interviews, and during STEM clubs.

Context

This investigation is part of a three-year National Science Foundation (NSF) ITEST grant serving four rural, high poverty, high minority middle schools. The focus of the NSF project is to increase the awareness of, interest in, preparation for, and intention of middle school students to continue in STEM courses, major in STEM, and possibly pursue STEM careers (Blanchard et al., 2014). The central focus of the project is the implementation of after-school STEM Career Clubs. This study was conducted during the third year of the grant cycle. Each of the STEM Clubs at the four middle schools were led by a group of teachers from each school (T-Coaches), located in two rural, high poverty middle school in the southeastern United States (U.S.). Research team members included faculty from science
education, educational psychology, educational technology, a postdoctoral fellow, a graduate student, and TPD staff from the university.

Teacher-Coach Professional Development

As part of the NSF grant, approximately five-seven Teacher-Coaches at each of the four intervention schools (28 T-Coaches, total) received teacher professional development at one of the school locations. The TPD took place from nine am to four pm on four Saturdays spread throughout the school year, and rotated to a different middle school for each session. On each TPD Saturday, university staff modeled the procedures in the manner and design they intended for the next three STEM Clubs to be conducted, with the teachers participating as a team as the students would, then adding instructional pointers. All STEM club activities highlighted at least one of the STEM content areas in each club. The T-Coaches were given all materials needed to reproduce the club activities with their students at their schools, packaged by club meeting (see examples in Figure 2.3). T-Coaches also received club agendas, and any packets or worksheets necessary for the meetings, to aid the T-Coaches in preparation and organization for their clubs (see Appendix G). After the TPD, T-Coaches were encouraged (and paid) to have a one hour PLC meeting before each club meeting to prepare for the club, which they facilitated. Ideally, the T-Coaches would have twelve PLC meetings each year in preparation for the twelve STEM Clubs. T-Coaches received ongoing support between the TPD sessions through frequent communication with the research team members via email and periodic visits to school sites.

This study focuses on two T-Coach teams during teacher professional development (TPD) intended to prepare them to lead STEM Club meetings four-six (December – February). At the Saturday TPD, the second of the year, the T-Coaches engaged in all of the
upcoming STEM Club activities, as if they were students (see Table 3.1). They also had time to ask about the content and reflect on details with their team members about how they would enact the clubs at their schools.

Table 3.1
Teacher Professional Development for STEM Clubs

<table>
<thead>
<tr>
<th>Club Meeting</th>
<th>Description</th>
<th>Intended Learning Goal</th>
<th>DoS Dimension Reinforced</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Saturday TPD 1 Preparation – Meetings 4-6</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td>Raspberry Pi Setup</td>
<td>T-Coaches learned how to set up a Raspberry Pi microcomputer. Once they understood how to correctly set up the Pi with the monitor, keyboard and mouse, their partner went into the hallway and a T-Coach &quot;sabotaged&quot; the Pi. When the partners returned from the hallway, they attempted to reconnect the Pi and restore it to working properly. They learned about microcomputers, troubleshooting and hardware connections.</td>
<td>Organization, Materials, Participation, Purposeful Activities, Engagement with STEM, STEM Content Learning, Inquiry, Reflection, Relevance</td>
</tr>
<tr>
<td>5</td>
<td>Raspberry Pi and LEDs</td>
<td>T-Coaches used Raspberry Pis and Scratch block-coding software to program a LED bulb attached to a breadboard. They learned about circuits, resistors, grounding, and electrical currents.</td>
<td>Organization, Materials, Participation, Purposeful Activities, Engagement with STEM, STEM Content Learning, Inquiry, Reflection, Relevance</td>
</tr>
<tr>
<td>6</td>
<td>Raspberry Pi and Stoplight</td>
<td>T-Coaches used Raspberry Pis and Scratch block-coding software to light up 3 LEDs in a particular sequence attached to a breadboard (a board for making an experimental model of an electric circuit) to simulate a stoplight. They learned about circuits, resistors, grounding and electrical currents, and learned more about coding through the Scratch software.</td>
<td>Organization, Materials, Participation, Purposeful Activities, Engagement with STEM, STEM Content Learning, Inquiry, Reflection, Relevance</td>
</tr>
<tr>
<td><strong>Saturday TPD 2 Preparation – Meetings 7-9</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Infectious Diseases</td>
<td>T-Coaches explored how infectious diseases spread on a small scale through the use of a network experiment. They then played Pandemic 2 online game (free), attempting to engineer a pandemic. The underlying programming uses the same mathematics used in the network model.</td>
<td>Organization, Materials, Space Utilization, Participation, Purposeful Activities, Engagement with STEM</td>
</tr>
<tr>
<td>Club Meeting</td>
<td>Description</td>
<td>Intended Learning Goal</td>
<td>DoS Dimension</td>
</tr>
<tr>
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</tr>
</tbody>
</table>
| 7            | Saturday TPD 2 Preparation – Meetings 7-9 | **Infectious Diseases**  
T-Coaches explored how infectious diseases spread on a small scale through the use of a network experiment. They then played Pandemic 2 online game (free), attempting to engineer a pandemic. The underlying programming uses the same mathematics used in the network model. | STEM Content Learning Inquiry Reflection Relevance Youth Voice |
| 8            | Evolution and Natural Selection | T-Coaches learned about selection and evolution through a hidden animals PowerPoint presentation and experimenting with picking up Skittles on different colored fabrics in a poorly lit room. They recorded their data in tables and plotted their results on histograms. | Organization Materials Space Utilization Participation Purposeful Activities Engagement with STEM STEM Content Learning Inquiry Reflection Relevance Youth Voice |
| 9            | Physiology             | T-Coaches get into groups and measure two students' vertical jump ability using jump boards affixed to the wall and magnets. T-Coaches then selected variables to measure (i.e., arm length, height) and wrote predictive equations on the first test student's jumping and then compare to the second test student's measurement. They test and reassess their equations. | Organization Materials Participation Purposeful Activities Engagement with STEM STEM Content Learning Inquiry Reflection Relevance Youth Voice |
Selection of Participating STEM Club Schools

The researcher wanted to select two schools as cases that represented the diversity of the four clubs (Creswell, 2014). There were a number of data sources that helped to determine which two clubs would be selected.

Dimensions of Success Scores

Three of the researchers on the project completed a two-day training, along with follow up calibration exercises on the Dimensions of Success (DoS) observation tool. The training was focused on how to implement the DoS taught by the PEAR institute. After receiving certification, the DoS Observation Tool was used at each study school for six of the club meetings (twelve meetings total) to evaluate the club across four domains. One or more of the research team members were present at each school for two or three club meetings and used the DoS observation tool (Papazian et al., 2013) to score each club’s success. Each of
the four domains: (a) how the club is organized, such as small group with one T-Coach in a classroom vs. large group with all T-Coaches in a cafeteria or multipurpose room; (b) the amount/extent of the activities that are covered for each club meeting; (c) how well the students are engaged and participating in STEM activities included in the tool and; (d) the preparation and T-Coach interaction throughout the club have three dimensions. The evaluation process started with the observer attending a STEM program and recording detailed field notes, including teacher and student quotes and accounts of what took place. After the observation, the researchers analyzed the field notes and placed corresponding 'evidence' from these field notes into each of the associated twelve dimension categories. Then, using the rubrics developed and provided by PEAR, the evaluator assessed the evidence and assigned the school a rating of one to four, based on the rubric for each dimension (1 - Evidence Absent; 2 - Inconsistent Evidence; 3 - Reasonable Evidence; 4 - Compelling Evidence).

The DoS scores for three STEM club meetings for all four schools in the overall grant project were compiled and compared, with the goal of selecting two of these STEM clubs (at two schools) for the comparative case study. Details of how this process took place will be explained later in this section.

Teacher Belief Interview

The Teacher Belief Interview (TBI) was used to measure teacher's teaching beliefs (Blanchard et al., 2016; Luft & Roehrig, 2007). The interview protocol was designed to capture the belief profiles of secondary science teachers and score their responses along a continuum from traditional (teacher-centered) to reform-based (student-centered). In this study, the TBI was administered as an online survey, similar to prior published work.
(Blanchard et al., 2016). Using scores from the fall and mid-year administration of the TBI, the responses were scored with two other researchers and averaged for each school. For the complete TBI see Appendix C, three of the seven items are:

- How do you maximize student learning in your classroom?
- How do you describe your role as a teacher?
- How do you know when your students understand a concept?

Club Structure

During the previous year and first six meetings of the school year, the researcher wrote descriptions of each of the clubs' structure (met with STEM Club students in large group vs. small group). The researcher logged which club structure was typical for each club.

TPD Attendance

Another data source was the attendance of the STEM Club T-Coaches from each school at the November TPD session. The research recorded how many T-Coaches from each team were present and absent.

PLC Meeting Implementation

Another factor considered in the selection of the two STEM clubs for the comparative case study was the number of times (out of six possible at the time of the research study) that each club held a PLC meeting before the STEM Club meeting.

Once the data was collected, results were analyzed for differences between schools (see Table 3.2). The DoS scores, TPD attendance, club structure, TBI scores, and implementation of PLC meetings were examined. Based on these data, the school that seemed most different from the other schools was Northern Middle School (MS). Northern
MS had the lowest average TBI score, they structured their club as a whole group (meeting in one large space for most of the club activities), they had the lowest number of T-Coaches at TPD, and lower occurrences of PLC meeting implementation. After recognizing that Northern MS would be one of the two study schools, the researcher looked at the club schedule and had the choice of either Eastern MS or Southern MS, which were scheduled on a different day than the Northern MS, and thus the researcher would be able to attend those meetings for data collection. Data from Southern MS was identified as the STEM club that was the most different from Northern MS. Therefore, the two schools selected for the cases were Northern MS and Southern MS.

Table 3.2

<table>
<thead>
<tr>
<th>Middle School</th>
<th>Club Meeting Day</th>
<th>Prelim Dos Scores (Highest possible score=48)</th>
<th>TPD 2 Attendance</th>
<th>Club Structure</th>
<th>TBI Average (4= highest)</th>
<th>PLC Meetings Held</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Thursday</td>
<td>35, 35, 35</td>
<td>2 Absent</td>
<td>Large Group</td>
<td>2.51</td>
<td>4/6</td>
</tr>
<tr>
<td>Eastern</td>
<td>Tuesday</td>
<td>39, 36</td>
<td>All Present</td>
<td>Small Group</td>
<td>2.83</td>
<td>6/6</td>
</tr>
<tr>
<td>Southern</td>
<td>Tuesday</td>
<td>42, 41, 41</td>
<td>All Present</td>
<td>Small Group</td>
<td><strong>3.06</strong></td>
<td>6/6</td>
</tr>
<tr>
<td>Western</td>
<td>Thursday</td>
<td>39, 38</td>
<td>All Present</td>
<td>Small Group</td>
<td>2.79</td>
<td>4/6</td>
</tr>
</tbody>
</table>

Approximately 300 students, ranging from sixth to eighth grade, attended Southern MS (Gorski, 2017). Southern MS, an “Early High School STEM Program,” was a unique middle school in that its application was lottery-based and it had only 13 teachers. Southern MS was open to students from diverse social and academic backgrounds, with the intention of recruiting students with high interest in science, technology, engineering and/or mathematics, regardless of academic giftedness or prior academic performance.

Northern MS had about 400 students ranging from fifth to eighth grade (Gorski, 2017). The student–teacher ratio at Northern MS was 15:1, which was lower than the state
average of 16:1, even though the school only employed 26 teachers. Northern MS was a traditional public school whose students were zoned to attend.

Participants

The T-Coaches from Northern MS and Southern MS were the participants in this study. Both schools had six teachers who had volunteered to become T-Coaches for the STEM Career Club after-school program, and to be a part of the original research study, and this dissertation study. These individuals were expected to take part in the TPD, PLC meetings, and after-school activities. T-Coaches also completed a survey on demographic, educational, and career status that was self-reported (see Appendix D). Data was collected during fall and spring of the study year. The Internal Review Board (IRB) at the university (NCSU) approved the proposed study on November 29, 2016, Protocol #9382.

Data Sources and Analysis

Qualitative data was collected during the T-Coaches’ PLC meetings (up to six) as they planned for the club meetings and during the six STEM Clubs implemented during this study and during teacher card sort activities.

PLC Meetings - Pre-Club Meeting Audio Data and Analysis

Prior to each club meeting, STEM Club T-Coaches met to review materials and to plan for the next student club meeting. STEM Club T-Coaches were strongly encouraged and paid if they attended PLC meetings (the anticipated length was 60 minutes), but they were not technically required. The research team provided checklists (see Appendix B) matched to each of the STEM club meetings for the T-Coaches to use as a guide their PLC work. During PLC meetings, T-Coaches were asked to audio record all of the planning meetings that were held, in order to capture the interactions they had as they worked through
the logistics of the club activities (see Appendix E for audio recording instructions). Audio recording was done to capture the interactions taking place, such as content coaching, material organization, activity practice, and general atmosphere of the team.

The audio was transcribed verbatim by a professional transcriptionist and open coded in Atlas.ti. Four PLC meetings (out of a possible five) from Northern MS were audio recorded, and three from Southern MS (out of a possible five), resulting in approximately three and a half hours of audio recordings and 200 double-spaced pages of transcription data. The first read-through of the transcripts was used to gain a general understanding of what was taking place; then, a second coding pass was used to document the activities of each of the T-Coaches throughout the PLC. The third pass was to code for the frequency of the T-Coaches actions, and the fourth pass was to code the statements of the T-Coaches into one of the three a priori characteristics CoP identifies for social learning (mutuality, repertoire, and enterprise) (see Table 3.3).
Table 3.3

PLC Meeting Coding Examples

<table>
<thead>
<tr>
<th>Example Transcribed Dialogue from PLC Meeting for Student Club Meeting #7- Infectious Disease</th>
<th>Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cynthia:</strong> We could write it down.</td>
<td></td>
</tr>
<tr>
<td><strong>Alisha:</strong> So, just know, like, a chart,</td>
<td></td>
</tr>
<tr>
<td>have them -</td>
<td></td>
</tr>
<tr>
<td><strong>Cynthia:</strong> Yeah, maybe on the white board,</td>
<td></td>
</tr>
<tr>
<td>we can say, &quot;When you think of diseases,</td>
<td></td>
</tr>
<tr>
<td>what other words? They spread by…with what?</td>
<td></td>
</tr>
<tr>
<td>Maybe they can come up with bacteria. They</td>
<td></td>
</tr>
<tr>
<td>should be able to with viruses.</td>
<td></td>
</tr>
<tr>
<td><strong>Alisha:</strong> And try to come up with some</td>
<td></td>
</tr>
<tr>
<td>other diseases.</td>
<td></td>
</tr>
<tr>
<td><strong>Michelle:</strong> The last two, like they said,</td>
<td></td>
</tr>
<tr>
<td>are probably going to be the toughest.</td>
<td></td>
</tr>
<tr>
<td><strong>Cynthia:</strong> Right. Protozoa, probably - so,</td>
<td></td>
</tr>
<tr>
<td>we'll make sure we write those down and talk</td>
<td></td>
</tr>
<tr>
<td>about them.</td>
<td></td>
</tr>
<tr>
<td>T-Coaches are discussing how they will</td>
<td></td>
</tr>
<tr>
<td>present the material to the students</td>
<td></td>
</tr>
<tr>
<td>T-Coaches Talking through probing questions</td>
<td></td>
</tr>
<tr>
<td>to ask students</td>
<td></td>
</tr>
<tr>
<td>T-Coaches discuss possible challenges for</td>
<td></td>
</tr>
<tr>
<td>students</td>
<td></td>
</tr>
<tr>
<td>Cynthia, Alisha, and Michelle discuss</td>
<td></td>
</tr>
<tr>
<td>pedagogy</td>
<td></td>
</tr>
</tbody>
</table>

**Dimensions of Success (DoS) Observation Tool and Analysis**

One or more of the research team members was present at each school for two or three club meetings and used the DoS observation tool (Papazian et al., 2013) to score each STEM Club's success. Three of the researchers on the project completed a two-day training, along with follow up calibration exercises on the Dimensions of Success (DoS) observation tool. The training was focused on how to implement the DoS taught by the PEAR institute.

After receiving certification, the DoS Observation Tool was used at each study school for 6 of the club meetings (twelve meetings total) to evaluate the club across four domains. Each domain had 3 dimensions (see Figure 2.1): (a) how the club was organized, such as small group with one T-Coach in a classroom vs. large group with all T-Coaches in a cafeteria or multipurpose room; (b) the amount/extent of the activities that were covered for
each club meeting; (c) how well the students were engaged and participating in STEM activities included in the tool and; (d) the preparation and T-Coach interaction throughout the club.

The evaluation process starts with the observer attending a STEM program and recording detailed field notes, with T-Coach and student quotes and accounts of what took place. After the observation, the observer or evaluator analyzed the field notes and placed corresponding 'evidence' into each of the associated twelve dimension categories. Then, using the rubrics developed and provided by PEAR, the evaluator assessed the evidence and assigned the school a rating of one to four based off the rubric for each dimension. These scores for four schools were compiled and compared. The schools in this study were given a dimension score for all twelve dimensions for six club meetings. These scores were then compared against the team interaction types and beliefs to success to analyze significance (DoS documents and sample notes can be found in Appendix A).

**Student STEM Club Meetings**

The researcher was present at all student club meetings at both schools during this study (twelve club meetings total). The researcher recorded which T-Coaches were present, and how many students were present. The DoS observation tool field notes were used to score each of the factors immediately following the club meetings (see Appendix A).

**T-Coach Card Sort and Think Aloud and Analysis**

T-Coach participants were asked to participate in a one-on-one card sort activity with the researcher at their school sites, during T-Coach planning period or after-school. Each T-Coach was handed a set of twelve cards created from the dimensions on the DoS observation
tool (see Appendix F). Each card had the dimension name and a brief description of the
dimension printed on the front (see Figure 3.2).

![STEM Content Learning](image1)

![Inquiry](image2)

*Figure 3.2 Example card from T-Coach DoS card sort*

The T-Coach was asked by the researcher to group the cards on the table from most
important (on the left side), in descending order, to less important, with the least important
dimension(s) on their right (Weller & Romney. 1988). The T-Coaches were told that more
than one card could be considered equally important (i.e., several cards could be placed at the
same importance level, and that there were no right or wrong answers, only their own
judgment). The T-Coaches were asked to think aloud while they worked through this
process (Boren & Ramey, 2000). The think aloud was captured on an audio recorder and the
researcher took a picture of each T-Coaches' final arrangement (see Figure 3.3). There was
no time limit for this task, which lasted from two minutes to nine minutes, with an average
time of seven and a half minutes.
Figure 3.3 Examples of T-Coach final arrangement of DoS card sort

**T-Coach Attendance Data**

The researcher recorded the T-Coach attendance at two TPD sessions, all PLC meetings that were held (five at each school), and at the six observed student club meetings. The researcher kept a record of the T-Coach attendance to analyze how T-Coach presence at TPD sessions, PLC meetings, and student club meetings influenced the DoS observation scores recorded.
CHAPTER FOUR

Findings: Case Study of Two STEM Clubs

This findings chapter will focus on the interactions that take place between the T-Coaches during PLC meetings and what tasks are being carried out at each and how this related to club DoS ratings. This section will be presented in two parts: Case one, Northern Middle School and Case Two, Southern Middle School. For each case, analyses of PLC team interactions as they prepared for STEM Clubs are presented. Then, a cross case analysis is presented.

Case One - Northern Middle School

Case Description

At Northern MS, six teachers make up the STEM Club Teacher-Coach team. The Northern MS team is a close-knit group of individuals, each of whom has distinct personalities and skills that contribute to the group (see Table 3.4).

Table 4.1

<table>
<thead>
<tr>
<th>Participant First Name (Pseudonym)</th>
<th>Race/Ethnicity* (Age)</th>
<th>Highest Degree</th>
<th>Gender</th>
<th>Content Area Taught</th>
<th>Years Teaching at this school</th>
<th>Years Teaching at this school</th>
<th>Time Involved with the Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alisha</td>
<td>AA (37)</td>
<td>Master's in School Leadership</td>
<td>Female</td>
<td>Science</td>
<td>14 Years</td>
<td>14 Years</td>
<td>3 Years</td>
</tr>
<tr>
<td>Candice</td>
<td>AA (28)</td>
<td>Bachelor's in Health Ed</td>
<td>Female</td>
<td>Science</td>
<td>3 Years</td>
<td>5 Years</td>
<td>3 Years</td>
</tr>
<tr>
<td>Cynthia</td>
<td>W (54)</td>
<td>Advanced Certification in AIG and Reading</td>
<td>Female</td>
<td>AIG</td>
<td>18 Years</td>
<td>27 Years</td>
<td>3 Years</td>
</tr>
<tr>
<td>Kevin</td>
<td>AA (28)</td>
<td>Bachelor's in Biology</td>
<td>Male</td>
<td>Science</td>
<td>2 Years</td>
<td>2 Years</td>
<td>2 Years</td>
</tr>
<tr>
<td>Linda</td>
<td>W (53)</td>
<td>Bachelor's in Education</td>
<td>Female</td>
<td>Math</td>
<td>9 Years</td>
<td>28 Years</td>
<td>2 Years</td>
</tr>
<tr>
<td>Michelle</td>
<td>W (47)</td>
<td>Master's in Elementary Education</td>
<td>Female</td>
<td>Science</td>
<td>11 Years</td>
<td>25 Years</td>
<td>3 Years</td>
</tr>
</tbody>
</table>

* AA= African American, W=White/Caucasian
Alisha, an African American female, taught eighth grade integrated science. She had been teaching for 14 years and held a master's degree in school leadership and a bachelor's in biology. She was involved in the STEM Club project since its beginning. Based on researcher observations, she was a team member who anticipated future club needs, and frequently reflected on how the STEM Club was going. She was often the person who planned specifics and she focused on solving problems. The researcher viewed Alisha as a dependable team member who, in every instance observed, followed through with her responsibilities to the club.

Candice, an African American female, taught seventh grade integrated science. She had five years of experience, and held a bachelor's degree in Health Education. Candice participated in the STEM Club program since its beginning. The researcher observed her as organized and technologically savvy. Based on researcher field notes, she usually took responsibility for preparing any technology needed for club meetings (i.e., reserving a laptop or iPad cart, preparing video links or websites). She didn’t indicate a desire for a central leadership role, but seemed to enjoy her responsibilities to make the STEM program run well.

Cynthia, a middle-aged White female, taught academically gifted (AIG) classes at two different middle schools in the county. She had 27 years of teaching experience and held advanced certification in AIG and Reading. She also joined as a STEM Club T-Coach at the beginning of the project. She seemed the most vocal, spunky and playful team member during PLC meetings, and excited about science topics. She often taught STEM Club content to her colleagues during PLC meetings and TPD.
Kevin, an African American male, was a second-year teacher who taught sixth grade integrated science. He was a lateral entry teacher who held a bachelor’s degree in Biology. He was becoming a certified teacher through teaching and coursework, rather than a degree in science education. Kevin was completing his second year with the project at the time of the study. Although he was one of the youngest team members, he often was observed taking the initiative and stepping up to challenges. For instance, he often helped the team overcome confusion over unfamiliar technology such as the Raspberry Pi microcomputer. Researcher field notes noted his asking questions at TPD sessions and exuding a passion for learning all the new STEM Club activities and technologies.

Linda, a White female, taught fifth grade math and had been teaching for 28 years. She held a bachelor's degree in education and had been involved with the program for two years. She was observed to have a similar role to that of Candice: very organized and dependable. She was responsible for collecting informed consent from the students and ensuring attendance was recorded. Researcher field notes indicated that she seemed satisfied with her responsibilities in the STEM Club.

Michelle, a White female science teacher, currently taught fifth grade integrated science. She had been teaching for 25 years and held a bachelor's degree in psychology, a master's degree in elementary education, and was also nationally board certified as a middle childhood generalist. She too had been involved in the project from the beginning. Michelle was considered the T-Coach coordinator or liaison at Northern MS. She was observed as focused and task-oriented. When interacting with both the students and fellow T-Coaches she seemed to have a nurturing, caring style. She took diligent notes during the TPD sessions.
and transcripts indicate that she referred back to her notes as she worked to prepare for the STEM Clubs during PLC meetings.

**PLC Meeting Interactions**

During PLC meetings, T-Coaches planned and coordinated tasks they needed to complete in preparation for the STEM Clubs. Northern MS audio recorded their PLC meetings associated with STEM Club meetings five, seven, eight, and nine (Northern MS did not hold a PLC Meeting #6). In the following section, an overview of each of the PLCs Northern MS held is given.

**PLC Meeting #5**

Meeting five was started and led by Kevin, one of four T-Coaches present at the corresponding TPD, who seemed the most confident and knowledgeable about the Raspberry Pi microcomputer. Kevin worked doggedly to get through all of the content with Candace and Alisha; he took out equipment and explained it; yet, Candace and Alisha did not handle the equipment, and asked few questions. When Candice suggested that the club have students meet in separate rooms, Kevin expressed concerns.

Kevin: Right, but the only thing about doing it [leading the club meeting] in separate classrooms is, if everyone doing [teaching the material] doesn't have a complete and full understand[ing] of what they're doing or teaching them [the students], then that's going to be, like, complete mind blown.

In short, Kevin seemed unsure that Alisha and Candace understood enough about the Raspberry Pis to lead the clubs in their own rooms with students, and was dissuading his colleagues from leading the activities in separate classrooms.
Candace and Alisha seemed more concerned with how the activity would be presented to students (pedagogy). They reviewed the content questions the students would be expected to complete after the lesson, and planned the logistics of the club meeting (i.e., who was responsible for supplies, set-up, professional speaker, and grouping). They ended the meeting by discussing how they missed one of the team members who had been absent recently, due to assignment at another middle school.

Candace: Wasn't it at one point she was coming here every other week, I thought?
Alisha: Oh, that's true too. I don't know. But we're going to reach out to her, be like, "We miss you. Where you at?"

Northern MS did not hold a PLC Meeting #6, which was intended to prepare them for the STEM Club in which students carried out additional tasks with Raspberry Pis.

PLC Meeting #7

A bomb threat at Northern MS required a Saturday make-up school day that conflicted with the planned TPD for meetings seven though nine. Therefore, Cynthia and Michelle were the only T-Coaches the principal would allow to attend the TPD, and it was up to them to learn what was needed for these three upcoming STEM Clubs and help their team get up to speed during the related PLC meetings. Michelle began PLC meeting number seven by leading group members through a quick synopsis of the TPD and the agenda related to the STEM Club meeting that focused on infectious diseases.

Michelle: Write down on a piece of paper the names of three other people in the room, in the STEM Club room, that they have had contact in some way with that day, somebody they talked to, somebody they passed in the hall, they saw in the lunch room, something.
Cynthia: Borrowed a pencil doesn't matter.

Michelle: And they'll just write the names down on a piece of paper. And then

Cynthia: Not show anyone else. That was our mistake.

Michelle: Yeah, because we cheat a little bit, of course.

Throughout the PLC meeting, Cynthia and Michelle answered questions, explained content, and expressed pedagogical ideas. Team members practiced the online game activity (Pandemic 2™) while Cynthia and Michelle gave them advice in a manner that seemed helpful and encouraging.

Cynthia: It doesn't matter about spelling. Who's going to really know? They're all going to be dead anyway. Okay. So, skip tutorial, because I'm just going to talk you through it.

-and-

Michelle: I'm going to tell you something else you can do that's helpful.

Cynthia: Yeah, she's good at it. Go ahead.

The team also discussed ways to increase student interest and understanding, indicating they placed a high value on the students' experience at club:

Cynthia: And everybody just kind of walk around and make sure they're going as fast as they can, because I think that will make it more interesting.

Cynthia: And if y'all will just walk around while they're doing this and just ask questions. "Hey, she's killing off more than you are. So, read off your symptoms, and we'll read off these. What's the difference?" And talk about that. Okay.
Following the Pandemic 2 explorations and tips, a large portion of the meeting was spent discussing how the activity would be presented to students and planning the logistics of the club meeting (i.e., who was responsible for supplies, set-up, professional speaker, and grouping).

PLC Meeting #8

Much like PLC meeting #7, because Cynthia and Michelle were the only T-Coaches who attended the TPD, it was up to them to help their team ‘get up to speed’ during the PLC meeting. Michelle began PLC meeting #8 by leading group members through the agenda related to the evolution and natural selection topics of the upcoming STEM Club. Throughout the meeting, Cynthia and Michelle answered questions, explained content, and expressed pedagogical ideas. The team worked through the PLC meeting checklist the research team provided for them assigning responsibility for tasks as needed. There was concern that storms forecasted for the upcoming club meeting might make it impossible to have students do the ‘Thicket Game’ (“Project Wild K-12 Curriculum & Activity Guide,” 1992) outdoors.

Cynthia: [We could do it inside.] That way we get to keep that [Thicket] game. Now wait a minute. We have curriculum night. Are they going to be decorating or using that at all?

Michelle: I would think so.

Candace: We could put them in the - or we could use the cafeteria.

Michelle: Yeah.

Candace: And we can say, "We need the auditorium".
Michelle: Well, our STEM Club is pretty much over by the time curriculum night starts. So, we should be okay.

The team members offered suggestions and talked out solutions for STEM Club-related issues.

Following approximately 15 minutes on content and materials review, the rest of the PLC was focused on issues concerning an upcoming residential weekend at the university and creating a list of student names, which was required by the school district office. T-Coaches named each STEM Club student and decided if he or she would be invited (or not) based on STEM Club attendance, academic grades (if they were failing any courses), and disruptive behavior.

Michelle: Jonathan Jackson?

Cynthia: I don’t know him.

Alisha: We haven’t had him at STEM Club.

Candace: Yeah, cross him out.

Cynthia: How many is that?

Michelle: That gives us 5, 10, almost - that’s 14.

Cynthia: So, let’s go to fifth grade.

The student invitation decision-making process was democratic, allowing members to voice their opinion or concern and once a verdict was made, they promptly moved onto the next student.

PLC Meeting #9

The shortest of the PLC meetings recorded, meeting #9, began with a brief discussion about collecting students’ permission forms for the upcoming residential weekend at the
university. Then, Cynthia reviewed the activities listed on the club agenda in the order they are listed. Cynthia explained to the group that students, after some trial jumps, would create a mathematical equation to predict a person's jumping ability. T-Coaches, who had missed the TPD and therefore were seeing the physiology activity for the first time, expressed that the activity seemed fun and exciting and that kids will enjoy it. Michelle and Cynthia frequently referred back to what they did at the TPD, how they learned from their mistakes, and how they imagined the students would do similar things, poking fun at themselves.

Cynthia: And then, we have a jumping experiment.

Michelle: I was not good at this, y'all. I was embarrassingly bad at this.

Cynthia: Well, I hurt my back, so that shows how old I am.

The other T-Coaches listened and only interrupted Cynthia's teaching for a clarifying question. As was typical of other PLCs, a portion of the meeting was spent discussing how the activity would be presented to students and planning the logistics of the club meeting (i.e., who was responsible for supplies, set-up, and grouping). This PLC also made an effort to bring in a professional speaker, showing they valued this experience for the students.

Kevin: He used to work over at the fitness center.

Cynthia: Do y'all know that person personally, that you're talking about?

Kevin: Yeah, he's my fraternity brother.

Cynthia: Oh, well. Can you pull strings and ask him?

Kevin: So, what time will he need to come?

Cynthia: He would need to come approximately 5:00, yeah, and to discuss, you know…

Alisha: His job.
Cynthia: Yeah, his job. And tell him what we're doing. We're doing the jumping experiment and all that, the sit-and-reach. [The speaker did come to the STEM Club meeting.]

Before ending the PLC meeting, Cynthia asked the group if they had any comments, questions, suggestions, or concerns. Alisha brought up the next TPD and Cynthia expressed how disappointed she was that she couldn't attend that day. Cynthia instructed them to “take good notes!”

*Northern MS PLC Summary*

The interactions from Northern MS's PLC meetings provide an understanding of their team dynamic and functioning as a PLC. This team spent a considerable amount of time attempting to teach one another what the club activities were about and the associated content, which was most likely due to the low attendance of the team members at TPD. These absences resulted in gaps in the knowledge of team members, and they used PLC time to address these gaps, which showed that the Northern PLC members cared about the success of the club meetings. Another regular focus area of every PLC meeting was planning for STEM Club procedures, routines, supplies, club structure, and logistics. These interactions showed that the T-Coaches have a certain way of doing things within their PLC (i.e., roles and responsibilities) and trusted each other's ability to complete a task. Interactions also provided evidence that, when an issue or challenge arose, the team was willing to work together in a democratic way in which each member's voice was valued. In many PLC interactions, T-Coaches clearly felt comfortable and acted relaxed with one another, exhibiting positive relationships between team members. The focus of the interactions between team members also indicated a high priority on student interest, engagement, and
comprehension. Typically, only one or two members dominated the conversation during the meeting, which seemed to result from the fact that two or more T-Coaches who had attended the TPD.

*Tasks Carried Out in Preparation for STEM Club Meetings*

There were a number of tasks that were carried out during the PLC as the T-Coaches were preparing for the STEM Clubs (see Figure 4.1 and Table 4.1). Each of these is detailed, below.

*Content Coaching (16%)*

While practicing the activities, it was common for Michelle, Cynthia or Kevin, all of whom had comfort with science and/or engineering and technology, to coach the other T-Coaches on content. T-Coaches would field questions and give explanations.

*Reviewing the Club Agenda (14%)*

Club agendas were designed by the research team to help T-Coaches understand the instructions of the activities, how long each should take, what type of groups students should be in and background information for review. T-Coaches used this agenda to guide their discussions during the PLC.
Figure 4.1 Activities performed at NMS PLC Meetings.

Practicing Club Activities (7%)

Practicing club activities during the PLC meeting was a common during the PLC time. The T-Coaches would pull out equipment the research project provided for them or bring up online videos to practice the activities they would lead with the students at the STEM Club meetings.

Organizing Materials (6%)

The Northern MS team spent time during PLC meetings to discuss the materials needed for the club meeting, where the materials were, and how they would be prepared; Candice or Alisha often completed this task.

Club Structure (5%)

Once the activities and content were covered, the Northern MS team would discuss club structure. This would include discussing club setting and environment, the order of events, or which students could or could not be grouped together.
Table 4.2

Frequency Coding Summary for Northern MS PLC Meetings

<table>
<thead>
<tr>
<th>Activity</th>
<th>PLC #5 Time</th>
<th>PLC #7 Time</th>
<th>PLC #8 Time</th>
<th>PLC #9 Time</th>
<th>Total Coded Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in Minutes</td>
<td>27:42</td>
<td>34:35</td>
<td>36:29</td>
<td>14:00</td>
<td>112:46</td>
</tr>
<tr>
<td>Total Coded Statements</td>
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<td>344</td>
<td>642</td>
<td>104</td>
<td>1316</td>
</tr>
<tr>
<td>Reviewing Agendas</td>
<td>32</td>
<td>55</td>
<td>94</td>
<td>17</td>
<td>198</td>
</tr>
<tr>
<td>Content Coaching</td>
<td>37</td>
<td>111</td>
<td>60</td>
<td>18</td>
<td>226</td>
</tr>
<tr>
<td>Practicing Club Activities</td>
<td>16</td>
<td>82</td>
<td>0</td>
<td>0</td>
<td>98</td>
</tr>
<tr>
<td>T-Coach Interest</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Club Structure</td>
<td>27</td>
<td>13</td>
<td>17</td>
<td>13</td>
<td>70</td>
</tr>
<tr>
<td>Pedagogy</td>
<td>20</td>
<td>18</td>
<td>3</td>
<td>7</td>
<td>48</td>
</tr>
<tr>
<td>Professional Speaker</td>
<td>12</td>
<td>13</td>
<td>0</td>
<td>22</td>
<td>47</td>
</tr>
<tr>
<td>Organizing Materials</td>
<td>25</td>
<td>21</td>
<td>21</td>
<td>13</td>
<td>80</td>
</tr>
<tr>
<td>Completing the Checklist</td>
<td>29</td>
<td>19</td>
<td>7</td>
<td>1</td>
<td>56</td>
</tr>
<tr>
<td>Assigning Roles</td>
<td>27</td>
<td>33</td>
<td>8</td>
<td>1</td>
<td>69</td>
</tr>
<tr>
<td>Residential Weekend</td>
<td>0</td>
<td>15</td>
<td>426</td>
<td>7</td>
<td>448</td>
</tr>
<tr>
<td>Other</td>
<td>31</td>
<td>10</td>
<td>26</td>
<td>0</td>
<td>57</td>
</tr>
</tbody>
</table>

Note: NMS did not hold a PLC meeting for club #6, *Percent over 100 as some statements were double coded

Assigning Roles (5%)

One part of completing the checklist is to assign responsibility for certain tasks.

There were certain team members that accepted the same roles for multiple club meetings.

For example, Candice was usually responsible for preparing materials associated with technology such as, a laptop with video links ready, a projector and screen, and speakers if necessary or a laptop cart.

Discussions of Pedagogy (4%)

The team would also discuss the ways in which they could best present information to students and facilitate activities. Although most group members would contribute, Cynthia was most frequently bringing up pedagogy during PLC meetings.
*Completing the Checklist (4%)*

During PLC meetings, Northern MS would spend time completing the checklist the research team had given them by accessing the link online at the STEM career awareness wiki page (https://stemcareerawareness.wikispaces.com).

*Professional Speaker (3%)*

Once the club structure and order of events was decided, Candice, Kevin or Alisha would bring up the professional speaker. As explained in the agenda, T-Coaches were given the option to play relevant career videos for their students at the end of the club meeting or try to bring in a professional speaker. Northern MS talked during PLC meetings about reaching out to professionals in their community and inviting them to speak at the student club meeting.

*T-Coach Interest (2%)*

Another theme was T-Coaches expressing interest in the planned club activities. They would make comments about how enjoyable they thought the activity was at the TPD or how the students are going to like the activities.

The PLC meeting would end with the T-Coaches ready and prepared to carry out club meetings. During the PLC meetings T-Coaches would plan and coordinate tasks they need to complete for the STEM Club to be successful. The majority of the coded statements supported two of the social learning characteristics (enterprise and repertoire) however; mutuality seems to be lacking in Northern MS's PLC meeting interactions. This is not to assume that this team has zero mutuality between members but to address the lack of evidence for it in the recorded interactions.
Case Two - Southern Middle School

Case Description

At Southern Middle School, six teachers made up the T-Coach STEM team, ranging from an outgoing, Latina female Spanish teacher to a soft-spoken Asian, female math teacher, to a serious, English male science teacher. The Southern MS team is a chummy group of individuals who each have diverse different personalities and skills that contribute to the group (see Table 3.5).

Table 4.3

<table>
<thead>
<tr>
<th>Participant First Name (Pseudonym)</th>
<th>Race/Ethnicity* (Age)</th>
<th>Highest Degree</th>
<th>Gender</th>
<th>Content Area</th>
<th>Years Teaching at this school</th>
<th>Years Teaching at this school</th>
<th>Years Involved with the Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celia A (48)</td>
<td>W (25)</td>
<td>Master's in Math Ed</td>
<td>Female</td>
<td>Math</td>
<td>2 Years</td>
<td>12 Years</td>
<td>1 Year</td>
</tr>
<tr>
<td>Mark W (25)</td>
<td>Bachelor's in Education</td>
<td>Male</td>
<td>Social Studies Spanish</td>
<td>3 Years</td>
<td>3 Years</td>
<td>1 Year</td>
<td></td>
</tr>
<tr>
<td>Rosa W (48)</td>
<td>Master's in Education</td>
<td>Female</td>
<td>Spanish</td>
<td>3 Years</td>
<td>30 Years</td>
<td>3 Years</td>
<td></td>
</tr>
<tr>
<td>Shayna AA (52)</td>
<td>Master's in Science Ed</td>
<td>Female</td>
<td>Science</td>
<td>2 Years</td>
<td>9 Years</td>
<td>3 Years</td>
<td></td>
</tr>
<tr>
<td>Tiara AA (24)</td>
<td>Master's in Marketing</td>
<td>Female</td>
<td>Science</td>
<td>1 Year</td>
<td>1 Year</td>
<td>1 Year</td>
<td></td>
</tr>
<tr>
<td>William W (46)</td>
<td>Bachelor's in Physics</td>
<td>Male</td>
<td>Science</td>
<td>5 Years</td>
<td>14 Years</td>
<td>3 Years</td>
<td></td>
</tr>
</tbody>
</table>

* AA= African American, W=White/Caucasian, A= Asian/Pacific Islander

Celia, an Asian woman, taught eighth grade math at Southern MS. She had a Master's degree in education. She had taught for ten years and joined the STEM Club in year three. She was noted as being knowledgeable about the STEM Club activities and the related content, and helped William teach content to the other T-Coaches on their team. The researcher observed Celia as a soft-spoken woman who didn’t seek out leadership roles, and seemed satisfied with her contribution to the team.
Mark, a White male, taught eighth grade social studies. He had three years of teaching experience and held a bachelor's degree in social studies education. He began working with the STEM Club in year three. He was forthright with his group members, willing to give suggestions about how a task should be handled or how a goal should be accomplished during TPD or PLC meetings. Occasionally this confidence and assertively came across as having a 'know it all' attitude. However, as one of the youngest team members, the students seemed to especially enjoy interacting with him at STEM Clubs.

Rosa, a Latina female teacher, taught Spanish courses for eighth graders at Southern MS. She had a master's degree in Education and thirty years’ teaching experience. She was a founding member of the STEM Club, serving as a T-Coach for all three years and also as its leader. Clearly, she was a ‘natural’ leader, helping the group stay focused, with a healthy dose of humor. She seemed to have a lot of fun with her team at both TPD and PLC meetings.

Shayna, an African American female, taught seventh grade integrated science. Shayna had taught for nine years and had a Master's degree in science education. She joined the STEM Club at the beginning of the project. Shayna focused on potential logistical challenges related to STEM Club activities, such as whether students would have had exposure to the content previously. She came across as a lively, funny, and caring team member. The researcher observed that she was close to Rosa, and they tended to joke around together in the group setting.

Tiara, an African American female, was a new science teacher who taught eighth grade integrated science. She was a lateral entry teacher with a Master's degree in business administration and a concentration in marketing. She was a relatively new T-Coach who
joined the team in year three. Although not outspoken, she often jumped in to explain content to the other group members and took responsibility for sorting the paper materials for STEM Clubs. She also joined in on the fun with Rosa and Shayna during PLC meetings. Field notes indicate she willingly accepted leadership roles, if asked.

William was a quirky, yet well-liked White British male who taught sixth grade integrated science at Southern MS. He had a bachelor's degree in Physics and had been teaching for 14 years. He was clearly respected by his peers, and had been a central member of the STEM Club since the beginning of the project. He was most often observed in the role of content expert and was asked many questions by his team members. He usually took responsibility for most of the technology-related needs (e.g., setting up video links, readying laptops, creating a Padlet™).

This team had one main leader, Rosa. She was in charge of organization, calendars and bookkeeping, communication with the research team and communication within their team. She coordinated the PLC meetings and how team members would carpool to the TPD sessions. She also helped with STEM Club snacks and other research-related tasks. However, Rosa was not typically the go-to person when a question or concern was about the activity content; that was William’s role. William was like Rosa's right-hand man, coaching the other T-Coaches on the activities and preparing the group to facilitate the club meetings.

This team was task-oriented and relational. The team atmosphere during PLC meetings and TPD was as if a group of friends were getting together to plan an event they were excited about. Having the club run smoothly and as planned seemed to be priority number one. The team at Southern MS was dedicated to attending TPD. Over the past year, Southern MS had all team members at every TPD session.
**PLC Meeting Interactions**

During PLC meetings, T-Coaches planned and coordinated the tasks they needed to complete for the STEM Club to be successful. Southern MS audio recorded their PLC meetings associated with STEM Club meetings five, six, and nine (Southern MS held a combined PLC Meeting for #7 and #8. However, they forgot to record the meeting. Therefore, data from this PLC was unavailable.).

**PLC Meeting #5**

For this PLC meeting, the audio recorder was not turned on until about halfway through the meeting. Tiara recapped what had taken place at the start of the meeting. During this meeting, led by Rosa, a considerable amount of time was spent revisiting the Raspberry Pi activity and content. Even though all team members had been present at the TPD, it was clear there were still aspects of the activity about which the T-Coaches didn't feel comfortable. They took out the equipment and worked through the activity together.

Once the T-Coaches felt more comfortable with the activity, they worked through procedural routines, materials, and club structure/location concerns. The team seemed to place faith in William to complete the difficult tasks. T-Coaches talked briefly about how to present the materials to the students and also created supplemental materials for the club meeting. A unique task this team took on was creating a Padlet (online bulletin board) for accessibility of video links.

These interactions indicate that the T-Coaches were focused on being able to lead the students through the activity successfully and wanted the students to learn. William was usually the team’s go-to person for an answer related to content, such as when he explained the focus of the Raspberry Pi activity for Club five:
William: Right. Well, the main thing is for them to try and figure out how to do the timing and the sequence to do traffic lights.

Rosa: That’s the hardest.

The interactions from this meeting also indicate that the T-Coaches felt open and comfortable with one another. While meeting, the team was playful, making jokes, signing songs, and laughing throughout the entire meeting.

Shayna: I’m about to break out in a Mary Poppins song in a minute.

Tiara: No. The Sound of Music, [singing] doe, a deer, a female deer, ray, a drop of golden sun.

Shayna: Boom, boom, boom.

Tiara: [Singing] Me, a name I call myself. Far, a long, long way to run.

Rosa: People, listen, listen one minute.

And later:

Shayna: Do English people hate when people try to sound English?

William: Why would we hate your making yourselves look like you’re an idiot?

PLC Meeting #6

This meeting began with the team reflecting on the previous club meeting; what worked, what didn't, and what they could improve on in the future. The T-Coaches discussed ways to best present the information for the students, learning from their previous experiences in school and previous clubs. They also took out the equipment and practiced the activity together, while William explained the content accurately (using correct terminology).
William: Right. So, if you put a ground pin from the GPIO into these and positive and negative into these, then you can - basically, then you’re going to connect the LED out somewhere, and the resistor back -

Rosa: Any point here if I’m putting here -

William: Right.

Members seemed interested, asking questions and engaging in the activity practice:

Some members took pictures of how the Raspberry Pi was connected to refer back to later during the Club meeting. The team also talked about creating supplemental materials such as the Padlet and Google docs™, which had not been modeled at the TPD:

William: Should I send all of you this picture or just put it on the Padlet?

Rosa: In the Padlet, that’s fine.

Tiara: Padlet is fine

The team spent time organizing supplies, discussing pedagogy, and logistics. Similar to the previous meeting, this meeting had many instances of joking and laugh.

Southern MS did not record PLC Meeting #7 and did not hold a PLC Meeting #8.

PLC Meeting #9

PLC meeting nine began with T-Coaches discussing the organization of the club (i.e., how long each task will take, where to set up certain materials). They discussed creating a supplemental data table for students to record their data from the experiment with little confusion. Team members joked around with one another throughout the meeting, while they set up materials that took a little extra physical effort (attaching vertical jump measurement boards to the walls). The team collectively talked through some logistical challenges, considering all suggestions.
Shayna: Are we hanging them now or waiting until…

Mark: I'd say wait until Monday, wouldn't you?

Shayna: We could put them [the boards] on them [the Velcro strips], and then just take them off.

Mark: Yeah. I say put them [the Velcro strips] on it [the wall], and then, that way, all you got to do is just, like, literally put it [the board] up there.

A large portion of the meeting was spent discussing how the activity would be presented to students and planning the logistics of the club meeting (i.e., who is responsible for supplies, set-up, professional speaker, and grouping).

William: Two classes?

Mark: Two classes, yeah.

William: Oh, classrooms. By the looks of things, from what we've had recently, that seems to be fine with me.

Rosa: Or do you prefer three?

William: It's been fine with two. It's not like it's been packed [referring to a low enough number of STEM Club students to only need two classrooms].

Southern MS PLC Summary

The interactions from Southern MS's PLC meetings provide an understanding of their team dynamics and functioning as a PLC. This team spent a lot of time teaching one another what the club activities were about and the associated content. Interactions between team members also indicated a high priority on student comprehension. They also focused on procedures, routines, supplies, club structure, and logistics at each PLC meeting. These interactions showed that the T-Coaches had a certain way of doing things within their PLC
(i.e., roles and responsibilities) and trusted each other's ability to complete a task. Interactions also provided evidence that when an issue or challenge arose the team was willing to work together in a democratic way, in which each member's voice was valued. PLC meetings included interactions indicating that the T-Coaches felt comfortable and relaxed with one another, and positive relationships between members. The T-Coach team at Southern MS felt comfortable sharing details of their lives with one another and clearly cared about each other as individuals.

Tasks Carried Out in Preparation for STEM Club Meetings

There were a number of tasks that were carried out during the PLC as the T-Coaches were preparing for the STEM Clubs (see Figure 4.2 and Table 4.2). Each of these is detailed, below.

**Organizing Materials (19%)**

The Southern MS team spent time during PLC meetings to discuss the materials needed for the club meeting, where the materials were, and how they would be prepared; these tasks were often completed by William, Celia, or Tiara.

**Content Coaching (15%)**

While practicing the club activities, it was typical for William or Tiara to content coach the other T-Coaches who needed help understanding the STEM content. It was common to hear William or Tiara assisting the other T-Coaches to comprehend the content.

**Practicing Club Activities (13%)**

Similar to reviewing the agendas, practicing club activities during the PLC meeting was common during Southern MS's PLC meetings.
Reviewing Club Agendas (9%)

Club agendas, designed by the research team, were created to help T-Coaches understand the instructions of the activities, how long each should take, what type of groups students should be assigned to, and background information for review.

Playful Teasing (9%)

Throughout the PLC meetings, the T-Coaches seemed relaxed and would joke around while completing the preparation tasks. It was noticeable that Rosa and Shayna enjoyed joking around together and usually brought one of the other group members into the joke. Mark and William would join into entertaining exchanges.

Personal/Social Dialogue (7%)

While having PLC meetings, the T-Coaches at Southern MS would have moments they talked about personal things or socially interacted with each other.
Table 4.4

Frequency Coding Summary for Southern MS PLC Meetings

<table>
<thead>
<tr>
<th>Activity</th>
<th>PLC #5</th>
<th>PLC #6</th>
<th>PLC #9</th>
<th>Total Coded Statements</th>
</tr>
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<tr>
<td>Time in Minutes</td>
<td>42:33</td>
<td>36:35</td>
<td>29:32</td>
<td>108:40</td>
</tr>
<tr>
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<td>449</td>
<td>300</td>
<td>1246</td>
</tr>
<tr>
<td>Reviewing Agendas</td>
<td>77</td>
<td>21</td>
<td>8</td>
<td>106</td>
</tr>
<tr>
<td>Practicing Club Activities</td>
<td>76</td>
<td>82</td>
<td>3</td>
<td>161</td>
</tr>
<tr>
<td>Content Coaching</td>
<td>69</td>
<td>100</td>
<td>13</td>
<td>182</td>
</tr>
<tr>
<td>Organizing Materials</td>
<td>72</td>
<td>61</td>
<td>106</td>
<td>239</td>
</tr>
<tr>
<td>Club Structure</td>
<td>26</td>
<td>3</td>
<td>29</td>
<td>58</td>
</tr>
<tr>
<td>Pedagogy</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>42</td>
</tr>
<tr>
<td>Creating Supplemental Materials</td>
<td>21</td>
<td>15</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>Playful Teasing</td>
<td>38</td>
<td>33</td>
<td>47</td>
<td>118</td>
</tr>
<tr>
<td>Personal/Social Dialogue</td>
<td>71</td>
<td>11</td>
<td>4</td>
<td>86</td>
</tr>
<tr>
<td>Residential Weekend</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Other</td>
<td>27</td>
<td>107</td>
<td>37</td>
<td>171</td>
</tr>
</tbody>
</table>

Note: SMS did not record PLC meeting #7 and did not hold a PLC meeting for club #8

*Club Structure (5%)*

Once an understanding of the activities and content were covered the Southern MS team would discuss club structure. This would include discussing club setting and environment, the order of events, or which students could or could not be grouped together.

*Discussions of Pedagogy (3%)*

The team would also discuss the ways in which they could best present information to students and facilitate activities. Although most group members would contribute, Shayna and Mark were most frequently bringing up pedagogy during club meetings.

*Creating Supplemental Materials (3%)*

In their effort to increase club effectiveness and efficiency the T-Coaches would create supplemental materials for the club meetings. These supplemental materials include but not limited to a Padlet (online bulletin board), PowerPoint presentation, and data tables.
Taking time during PLC meeting to create and refine these supplemental materials was something Southern MS made a priority.

The PLC meeting would end with the T-Coaches ready and prepared to carry out club meetings. During the PLC meetings T-Coaches would plan and coordinate tasks they need to complete for the STEM Club to be successful. In the case of Southern MS, all team members were present at TPD and about five team members at all PLC meetings. Therefore, they seemed to have more time to devote to other activities during the PLC beyond learning content (such as creating supplemental materials, social and personal dialogue, and organizing materials).

**Cross Case Analyses**

In the cross case analysis between the two study schools, Northern and Southern MS, consists of the average DoS rating scores from club implementation.

*Dimensions of Success (DoS) Ratings*

DoS rating averages for both schools over six club meetings are used as descriptive outcomes. The ratings of club success are meant to better understand if certain T-Coach team interactions and higher functioning CoP within their PLC are related to more desirable DoS ratings (score of 3 or 4; 1-Evidence Absent; 2-Inconssisitent Evidence; 3-Reasonable Evidence; 4- Compelling Evidence). Table 4.3 displays the average DoS ratings for both Northern and Southern MS. The presence of a checkmark signifies a desirable for each domain and dimension.
Table 4.5
DoS Average Ratings for Northern and Southern MS

<table>
<thead>
<tr>
<th>Domain</th>
<th>Features of the Learning Environment</th>
<th>NMS</th>
<th>SMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension</td>
<td>Organization</td>
<td>3.6</td>
<td>✓</td>
</tr>
<tr>
<td>Dimension</td>
<td>Materials</td>
<td>4</td>
<td>✓</td>
</tr>
<tr>
<td>Dimension</td>
<td>Space Utilization</td>
<td>3.8</td>
<td>✓</td>
</tr>
<tr>
<td>Domain</td>
<td>Activity Engagement</td>
<td>2.9</td>
<td>3.4</td>
</tr>
<tr>
<td>Dimension</td>
<td>Participation</td>
<td>2.8</td>
<td>3</td>
</tr>
<tr>
<td>Dimension</td>
<td>Purposeful Activities</td>
<td>2.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Dimension</td>
<td>Engagement with STEM</td>
<td>3</td>
<td>✓</td>
</tr>
<tr>
<td>Domain</td>
<td>STEM Knowledge and Practices</td>
<td>2.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Dimension</td>
<td>STEM Content Learning</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>Dimension</td>
<td>Inquiry</td>
<td>3.2</td>
<td>✓</td>
</tr>
<tr>
<td>Dimension</td>
<td>Reflection</td>
<td>2.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Domain</td>
<td>Youth Development in STEM</td>
<td>3.1</td>
<td>✓</td>
</tr>
<tr>
<td>Dimension</td>
<td>Relationships</td>
<td>4</td>
<td>✓</td>
</tr>
<tr>
<td>Dimension</td>
<td>Relevance</td>
<td>3</td>
<td>✓</td>
</tr>
<tr>
<td>Dimension</td>
<td>Youth Voice</td>
<td>2.2</td>
<td>2.5</td>
</tr>
</tbody>
</table>

7/12 Dimensions 2/4 Domains
11/12 Dimensions 4/4 Domains

Note. Ratings are 1-Evidence Absent; 2-Inconsistent Evidence; 3-Reasonable Evidence; 4-Compelling Evidence

Although both schools received identical TPD, club materials, and PLC checklists, the two schools differed in their club success based on the DoS observation tool results. Northern MS met desirable rankings for seven out of twelve dimensions (58%), which translates to achieving desirable ratings for two out of the four domains. Southern MS proved more successful, achieving desirable DoS ratings in eleven out of twelve dimensions (92%), translating to all four domains.

DoS results show some areas in which the two clubs are performing similarly. They both averaged desirable ratings in Space Utilization, showing both schools were able to provide a space adequate for the STEM activity that was both informal and free of
distractions. Both schools averaged desirable scores in the Materials dimension suggesting they were able to provide materials that were appealing and appropriate for the students. The schools also had desirable ratings in Inquiry, which indicates that the students were able to practice STEM activities in authentic ways. The two study clubs were also able to maintain a desirable rating in Relationships showing they created a positive environment that was warm and welcoming and all roles were interacting well (student-student, T-Coach-T-Coach, and Student-T-Coach). Lastly, the clubs were similar in the Relevance dimension, which indicates that the T-Coaches made connections to broader context and students were involved in discussions of relevance.

The dimensions recorded with the most variation between schools were Purposeful Activities, Reflection, and STEM Content Learning. In reference to Purposeful Activities, Northern MS tended to have more down time where students were not always focused on activities that would bring them closer to the learning goal (i.e., playing games on the Raspberry Pi) showing inconsistent evidence, resulting in a rating of a two. Southern MS kept students busy with activities that would continue to bring them closer to the learning goal showing compelling evidence, which resulted in their score of a four. In regards to Reflection, Northern MS would cease prompting students to reflect after a few responses showing inconsistent evidence resulting in their score of a two. Southern MS would continue to ask questions before and after the activities showing compelling evidence, resulting in a higher score of four. Southern MS also had a higher score in STEM Content Learning, as they tended to use specific terms associated with equipment (i.e., HDMI cord, Ethernet port) whereas Northern MS received a lower score with superficial terms (i.e., cord, wire).
CHAPTER FIVE

Findings: Teacher Beliefs and STEM Club Implementation

This findings chapter concentrates on the T-Coaches beliefs about the STEM club dimensions of success and how these beliefs influence actions as seen through observations using the DoS observation tool.

T-Coaches’ Beliefs about STEM Club Dimensions

After T-Coaches completed the card sort activity, their arrangements were ranked based on the position of the cards. The cards could have been ranked from one (most important) to twelve (least important) depending on how many dimensions T-Coaches stacked in equal importance (see Figures 5.1).

![Figure 5.1. Kevin's and Candice's card sort examples.](image)

Table 5.1 shows the T-Coaches' card sort results from Northern and Southern MS. The table displays each T-Coach rankings of each dimension, the average rank for each dimension and domain form the six T-Coaches, and how many of the six T-Coaches ranked
the dimension a one or a two. The T-Coaches' rankings of a one or two indicated that the T-Coach found these constructs most important, and those ranked with a one or a two were considered 'most important'.
### Table 5.1

**Northern MS and Southern MS T-Coach Card Sort Rankings**

<table>
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For T-Coaches at Northern MS, there were at least two of the six T-Coaches who ranked each of the twelve DoS constructs as either most or next most important. The fewest number of dimensions ranked one or two was three (Kevin and Michelle) and the largest number ranked one or two was eleven (Cynthia). On average, Northern MS T-Coaches grouped the cards into six categories. When averaged, the T-Coaches ranked the Youth Development in STEM domain as most important for STEM Club success (2.8 avg.). Activity Engagement was ranked second most important (3 avg.), then STEM Knowledge and Practice (3.7 avg.), and finally, Features of the Learning Environment (4.1 avg.). The most important dimension to Northern MS T-Coaches on average was Relationships (2 avg.), followed by Participation (2.5 avg.), and the least important was Space Utilization (4.8 avg.).

For T-Coaches at Southern MS, there was at least one of the six T-Coaches who ranked each of the constructs as either most or next most important. The fewest number of dimensions ranked one or two was two (Celia and Mark) and the largest number ranked one or two was twelve (Tiara). On average, T-Coaches grouped the cards into six categories. Southern MS T-Coaches ranked the Activity Engagement domain as most important for STEM Club success (2 avg.). Youth Development in STEM was ranked second most important (3.5 avg.), then STEM Knowledge and Practice (3.9 avg.), and finally, Features of the Learning Environment (4 avg.). The most important dimension on average was Engagement with STEM (1.3 avg.), followed by Activity Engagement (2 avg.), and the lowest was STEM Content Learning (4.7 avg.).

While completing the think aloud part of the card sort activity, T-Coaches explained their reasoning for placing cards in the order they did, as they worked. Because the T-
Coaches worked together at their respective STEM Clubs, the reasoning of the T-Coaches will be described by school.

Northern MS

It was most common for Northern MS T-Coaches to express feeling that Relationships with students were the most important (avg. rank 2) for STEM Club success and why:

Michelle: All right. Well, my first gut reaction is the Relationships is going to be most important, because that's how we're going to get them [students] there [to show up at the club]. And we've got to get them there before we can do anything else. So, that's why I'm putting that one first.

Candice: I really like the relationship. I think it's really important. And I kind of said earlier that I learned that the students, if they don’t like me, then they don’t really want to hear anything I've got to say.

Although most of Northern MS's T-Coaches expressed that they felt that Materials were linked to Participation, the average card sort ranking shows relatively low importance (3.7 avg. score). Three T-Coaches, Cynthia, Alisha and Candice, rated Materials as high in importance.

Cynthia: Okay. All right. Materials are important, because if your materials are blah, they're [students are] not going to be excited. So, I'm going to put that not first, but…

Kevin, who had rated Materials as least important (7), commented:

Kevin: And then, when it comes to materials, materials are important, but materials aren't necessarily needed to teach a student about STEM. And when it comes to materials, you don’t have to have the most expensive of materials. You can go to the dollar store and find some stuff that can be put together. I mean, I can't build a computer from the dollar store, but I can kind of figure other things out to kind of get the students to where I want them to go.

Half of the Northern MS T-Coaches also described that Organization was important but the card sort average ranking (3.7) was low.
Michelle: And I'm hoping I'm not just saying organization isn't as important because I'm not organized always. But, yet, we have to be. It doesn't go as well when we're not organized.

Linda: I think the organization is more for the adults. They [students] just see it as fun. And the fact that it's organized means they get to have more fun, because they're not sitting around, "Okay, how do we get this to work?"

Alisha seemed concerned with Materials and Organization and she explained it was because the NSF funding was at the end of its three year project and she wanted the STEM Club to continue at Northern MS:

Alisha: Okay. So, most important to me is organization and materials. So, as we talk about sustainability, we're concerned that, if we don't get our funding, then how are we going to keep our STEM meeting going? The materials and organization. So, those two are most important.

Southern MS

T-Coaches from Southern MS expressed the belief that Engagement with STEM was most important for STEM Club success and why. Mark explained that without Engagement with STEM the club would not be successful:

Mark: Okay. I started off with purposeful activities, engaging with STEM, because those, to me, are the most important things. If it's not purposeful and there's not engagement, then obviously the club will never succeed.

During the card sort, Southern MS T-Coaches also explained why they believed Purposeful Activities were important to STEM Club success. Tiara explained that for the club to be successful, the activities must be aligned with the goals of the STEM Club.

Tiara: Purposeful activities. I feel like this is important, because there's no need to have an activity that does not relate to a STEM program if it's not a STEM activity.

Rosa believed the Purposeful Activities dimension was important for the Organization of the club:

Rosa: And having a purpose for the activities, that's important. I mean, we need to have the structure.
The T-Coaches at Southern MS disagreed on their beliefs about the importance of

*STEM Content Learning*. Mark shared that for him, *STEM Content Learning* was not a focal point but Shayna believed content needed to be taught to reinforce relevance:

Mark: The STEM content learning is after that, and it is important, but if you're doing all the rest of these, then the content learning will come naturally.

Shayna: So, we want to make sure that we're aligned with different content areas, and multiple content areas is even better, and showing the students how relevant that content is in their everyday life, and having these activities that involve bringing the career into the fold kind of connects all of these together. "I'm learning this because of these reasons."

Southern MS T-Coaches expressed how important they believed *Youth Voice* was in their card sort but this was their lowest dimension score from observations. Tiara believed the students' point of view was important for their sense of ownership, Celia believed it was a key for learning, and Mark believed it was a way to troubleshoot issues.

Tiara: Youth voice, I feel, is most important, because what's the point of, you know, doing something for the children and you don't get to hear their input or how they feel about something?

Celia: Okay. So, for them to learn, they should do it their way. They should have a voice in the activity that they're having.

Mark: We want the students to have an ability to talk. And if there's problems or suggestions, let us know, let us know what they think about it.

T-Coaches' expressed feelings that certain aspects of the DoS were more important than others. Most T-Coaches expressed struggling with their decisions because they felt a lot of the dimensions were important and that none were unimportant. The think aloud quotes provide a better understanding as to why T-Coaches ranked dimensions of the card sort the way they did.
**Club Dimensions of Success Observation Ratings**

While observing Northern and Southern MS over the course of six STEM Club meetings, certain patterns became apparent. As seen in the summary Table 5.2, the evidence suggests that Northern MS's and Southern MS's strongest domain was the Features of the Learning Environment (3.6 avg. and 3.9 avg.)

Table 5.2

Northern and Southern MS DoS Rating Summary

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<td>3</td>
</tr>
<tr>
<td></td>
<td>Ave</td>
<td>3.3</td>
<td>3.7</td>
<td>3.7</td>
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<table>
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<tbody>
<tr>
<td></td>
<td>NMS</td>
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<td>3</td>
<td>2.7</td>
<td>3</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Relationships</td>
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<td>4</td>
<td>4</td>
<td>4</td>
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</tr>
<tr>
<td></td>
<td>Relevance</td>
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<td>3</td>
<td>2</td>
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<tr>
<td></td>
<td>Youth Voice</td>
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<td></td>
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<td></td>
<td>Youth Voice</td>
<td>3</td>
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</table>

*Note: Ratings are 1- Evidence Absent; 2- Inconsistent Evidence; 3- Reasonable Evidence; 4- Compelling Evidence*
The Youth Development in STEM also averaged the desirable rating (3.1 avg.) for Northern MS, although the dimension *Youth Voice* (2.2 avg.) could have been improved. The average DoS ratings indicated that Northern MS's strongest dimensions were *Relationships, Materials, and Space Utilization*. In addition to *Youth Voice*, *Reflection* (2.3 avg.) was another area that could have used attention. Table 3.4 also indicates that Northern MS could have used more improvement in *Activity Engagement* (2.9 avg.) and *STEM Knowledge and Practices* (2.7 avg.).

However, for Southern MS all four domains averaged desirable ratings (3 or 4). Eleven out of twelve dimensions met desirable ratings for Southern MS. The only dimension that was less than desirable was the *Youth Voice* dimension (2.5 avg.).

Some differences between these two schools can be identified in the *STEM Content Learning, Inquiry, and Reflection* dimensions. According to field notes, Southern MS was able achieve a higher score than Northern MS in *STEM Content Learning* as their students tended to use correct terminology and began to differentiate between concepts learned during the meeting and previously learned. Southern MS was always prepared and had materials and supplies ready to be used, which resulted in higher DoS ratings than Northern MS who many times had to run back to classrooms to obtain supplies for club. Northern MS also stopped probing students to reflect after only a few responses where Southern MS continued to question students to get them to make deeper connections. Neither school performed well in *Youth Voice*.

*T-Coaches Observed Practices Compared to Beliefs*

Analysis of the DoS ratings and T-Coaches' card sort results indicated that some of the dimensions were being addressed during student club meetings, resulting in desirable
DoS ratings, and others were not. It was found that T-Coaches simply believing a dimension was important and attending student club meetings would not necessarily result in desirable DoS scores. T-Coach attendance at TPD, PLC meetings, and student club meetings were compared the DoS dimension ratings, and T-Coach card sort rankings and all seem to have an influence on club outcomes.

After analyzing all situations, the researcher identified five different scenarios for DoS outcomes: Full Preparation, PLC only Preparation, No TPD or PLC Preparation, No PLC Preparation, and Unvalued Preparation. During the course of the study, Northern MS displays all five scenario types. However, due to the fact that Southern MS's whole team attended both TPD sessions, they did not have any situations with PLC only Preparation or No TPD or PLC Preparation scenarios, as both scenarios are situated around the team member missing the TPD session. Table 5.3 displays the type of preparation for each team member for the six STEM Club meetings at their schools. This data shows that Northern MS had more of a variety of the scenarios than Southern MS. Each of the scenarios is described below.
Table 5.3

T-Coach Scenario Occurrences

Note: This table does not include the Unvalued Scenario, as it is dependent on each dimension.

The Full Preparation scenario was when a T-Coach believed a dimension was important, they attended the TPD session and PLC meeting associated with the student meeting and then that individual led the student meeting with at least one other T-Coach who believed the same, resulting in a desirable DoS rating (see Figure 5.2). This scenario was the most ideal for STEM Club success.

Figure 5.2. The Full Preparation scenario flow diagram
Examples of the Full Preparation scenario could be found in several of Northern and Southern MS STEM Club meetings, one in particular was during Northern MS's meeting four. Candice and Michelle both believed student Participation at STEM Club was a top priority for success as they ranked participation second in rank order in their card sort activities. Both Candice and Michelle attended the TPD engaging in the activities presented and making plans and asking questions. Both attended the PLC meeting associated with meeting four where they reviewed the activities and led other group members through the content as observed through the PLC meeting audio data. Both Candice and Michelle were present at the student club meeting where they were engaged with leading the activities and interacted meaningfully with the students as recorded on the DoS observation field notes. Northern MS received a desirable DoS rating in this dimension (rating of a 3).

Full Preparation scenario was most often the case for Southern MS's STEM Club meetings; in fact, from the six meetings observed only six out of possible 72 scores of Southern MS's dimensions were rated undesirable. This success was likely due to the team's high attendance at TPD and PLC meetings.

Another scenario, PLC Only Preparation was when a T-Coach believed a dimension was of top priority, was absent from the TPD but attended the PLC meeting (where they learned and became prepared to lead the student meeting) and led the student meeting with at least one other T-Coach who believed the same, resulting in a desirable DoS outcome (Figure 5.3).
Figure 5.3. The PLC Only Preparation scenario flow diagram

An example of the PLC Only Preparation scenario came from Northern MS’s club meeting eight. Cynthia, Michelle, and Candice all believed the Engagement with STEM dimension was a top priority for STEM Club success as recorded through their card sort rankings. Michelle said during her card sort “then, participating and being engaged. I like those four. Those are definite.” However, Candice was absent from the TPD as noted in attendance data and Michelle was not present at the student meeting as noted in the DoS filed notes. Cynthia was the only T-Coach at the club meeting with Full Preparation as she was present at TPD and PLC meetings. Because Candice was present at the PLC meeting, and she was very focused on trying to learn what she has missed at the TPD, she was able to learn and prepare for the student club meeting, allowing her to act on her beliefs. Combined with Cynthia’s full preparation and Candice’s PLC only preparation resulted in a desirable DoS rating for the Engagement with STEM dimension during meeting eight (score of a 4).

In contrast, the No TPD or PLC Preparation scenario was when a T-Coach believed a dimension to be important but was absent from both TPD and PLC meeting, but present at the STEM club meeting (being unprepared and unable to meaningfully lead the student
meeting) with only one other T-Coach who believed the same, resulting in a less than desirable DoS rating (Figure 5.4).

![Diagram](attachment:diagram.png)

*Figure 5.4. The No TPD or PLC Preparation scenario flow diagram*

An example of the No TPD or PLC Preparation scenario was from Northern MS's meeting five. Although, two T-Coaches were present at the STEM Club who believed *Engagement with STEM* is a top priority, as noted through their card sort rank order (Cynthia and Candice), Cynthia did not attend the TPD or the PLC meeting, therefore she was unprepared and unable to meaningfully lead the student meeting as observed in the DoS field notes, resulting in a less than desirable DoS rating (score of a 2).

The No PLC Preparation scenario was when a T-Coach believed a dimension is important, attended the TPD, was absent for the PLC meeting, but attended the student meeting unsure of exactly what they were doing and unable to contribute in a meaningful way, resulting in an undesirable DoS outcome (Figure 5.5).
Figure 5.5. The No PLC Preparation scenario flow diagram

The No PLC Preparation scenario could be found in Northern MS's club meeting five in which two T-Coaches (Kevin and Cynthia) who believed the Reflection dimension was a top priority were present. Unfortunately, Kevin, who was present at the TPD session, was not present at the PLC meeting. He was unable to contribute in a meaningful way to students' reflection resulting in an undesirable DoS rating on the Reflection dimension.

A No PLC Preparation scenario took place during Southern MS's club meeting seven. Rosa and Tiara both ranked the Youth Voice dimension as a top priority for STEM Club success in their card sort activities but Tiara was absent from the PLC meeting (attendance data). Tiara was not prepared to lead the STEM Club meeting in a way that would enhance this dimension as described in the DoS observation field notes, resulting in an undesirable DoS rating (score of 2).

The Unvalued Preparation scenario occurred when only one T-Coach or no T-Coach at the club meeting believed a dimension was important. Whether they attended the TPD or PLC meetings or not, the dimension may not be met (Figure 5.6).
Figure 5.6. The Unvalued Preparation scenario flow diagram

An example of the Unvalued Preparation scenario from Northern MS was found during meeting four and meeting six. At both club meetings, only one T-Coach was present who believed *Purposeful Activities* should be a top priority for STEM Club success (Candice, who rank ordered Purposeful Activities as #1 in her card sort). As a result, the team received an undesirable rating (DoS score of a 2), which only happened under these two circumstances.

An example of this scenario at Southern MS was during their club meeting nine. Shayna and Tiara both believed the *STEM Content Learning* dimension was of top priority to STEM program success as described in their card sort activity dialogue but only Tiara was present at the club meeting. Having only one T-Coach present at the club meeting who believed this dimension is a top priority, led to the T-Coaches not as prepared to guide students toward the learning goals during this meeting as described in the DoS observation field notes, which resulted in an undesirable DoS rating (score of a 2).
Summary

After close examination of Northern and Southern MS's T-Coach attendance at TPD, PLC and student club meetings against the DoS dimension ratings and T-Coach card sort rankings, all seemed to have an influence on club outcomes. Five different scenarios were identified from this analysis: Full Preparation, PLC Only Preparation, No TPD or PLC Preparation, No PLC Preparation, and Unvalued Preparation. These scenarios help explain why some of the dimensions were being addressed during student club meetings, resulting in desirable DoS ratings, and other dimensions were not. These results provide evidence that when T-Coaches believed a dimension was important, it didn’t necessarily translate into desirable DoS scores.
CHAPTER SIX

Discussion

In the discussion of the two study schools, Northern and Southern MS, the interactions at PLC meetings are addressed first, followed by what tasks were carried out in preparation for STEM Club meetings, how these may contribute to the average DoS rating scores, and finally, how T-Coaches’ beliefs influence observed practices.

PLC Meeting Interactions

Enterprise

Using Wenger's (2000) terms, both schools interacted in ways associated with enterprise (learning energy within a CoP). For example, the T-Coach teams would spend time during PLC meetings teaching each other about the STEM content or practicing the STEM Club activities. T-Coaches also took time to learn the content questions (and answers) the students would be expected to answer at the end of the club meeting. This is similar to Owen (2015) who found that the most influential part of the PLC was the teachers learning within the PLC, which was attributed to co-planning, co-teaching, and creating co-assessments. Ronfeldt et al. (2015) also found that better quality collaboration (i.e., teachers' perception of how helpful and extensive the collaboration is) in PLCs enhances teachers' classroom performance.

However, there were differences in how they spent their time in teams. Northern MS spent more time on content coaching one another and reviewing the agendas than did Southern MS, perhaps as a result of Northern MS's low T-Coach turn out at the TPD sessions. That is, the T-Coaches who were present at TPD had to teach their Northern MS colleagues, who were absent (for one of the TPD’s, not allowed to attend), what they learned.
Coaching team members is an indicator of enterprise, what Wenger (2000) calls 'addressing gaps in knowledge'. Miranda and Damico (2015) also reported similar practices with teachers in PLCs stating that the teachers further developed their understanding of reform-based practices, modified their beliefs about teaching and learning, and changed their observed practices as a result of support and suggestions from other teachers. Southern MS had all T-Coaches in attendance at the two TPD sessions during this study, which indicated they kept learning at the center of the PLC (a signal of enterprise within a CoP). Having been trained at the TPD allowed them to use the PLC meeting for other tasks. Both schools have sought out learning opportunities (enterprise indicator) by attending TPD and holding PLC meetings. Mizzi (2013) reported that this is especially important when teachers are teaching content outside of their area of expertise which was almost always the case for the T-Coaches in both schools.

**Repertoire**

Northern and Southern MS also showed considerable results that suggest that they were enhancing their community repertoire at PLC meetings. Indicators of repertoire found during both schools PLC meetings included language, methods, standards, routines, and tools. For example, the T-Coaches assumed certain roles, they talked to each other with certain terms and tone, they each had difference routines of how the PLC was conducted and they also seemed to have certain standards about attendance and participation.

However, Southern MS routines seemed more focused on organizing materials, creating supplemental materials, and their technical language was more advanced compared to Northern MS. Northern MS discussed bringing in a professional speaker to speak at the student club meeting and expressed high interest in the club activities, unlike the T-Coaches.
at Southern MS. Both schools interacted in ways (i.e., reflecting on a prior club meeting and discussing strengths and weaknesses) that suggested they were reflecting on their practices to enhance their community of practice. Robertson and Jones (2013) described similar findings where teachers believed that the PLCs positively impacted their science practices as well as their lesson planning, though discussions on strategies for inquiry teaching (i.e., sharing lab materials, books, and other resources for teaching specific science topics).

**Mutuality**

Northern and Southern MS both showed results to suggest that they were engaging in mutuality at PLC meetings. Indicators of mutuality include having a deep sense of each other, trusting members personally and in their abilities, and communicating truthfully and interacting effectively. For example, the T-Coach teams trusted each other in their abilities to lead the STEM Club activities and they communicated truthfully and effectively during PLC meetings.

Although both schools seemed to have trust and communication between members (indicators of mutuality), Southern MS had more interactions of playful teasing and personal/social dialogue in their club meetings when compared to Northern MS. Though this is not explicit within the CoP framework, the evidence indicates that the Southern MS PLC members appreciated each other as individuals, cared about one another, and felt comfortable enough with one another to joke around, sing, and be silly together. Thus, based on the data, Southern MS's interactions indicated that their social capital (interpersonal relationships) was stronger than that of Northern MS as they seem to achieve what Wenger refers to as a 'deep sense of one another'. Mizzi (2013) similarly found teachers reported that their group functioned well and that the science PLC helped them “feel more like a team instead of just a
bunch of teachers” (p. 1768). However, unlike this study, most of the teachers (63%) talked about significant problems with interpersonal relationships and communication styles within the group. Two teachers noted, “PLCs can really work as long as you have cooperative people” and “they are not effective when you don’t get along” (p. 1768). These results show that dynamics between PLC members an important factor when working together for a common goal.

The evidence for this study suggests that Southern MS was achieving a deeper level of social learning in their PLC by exercising all three characteristics (enterprise, repertoire, and mutuality) more fully than Northern MS (Wenger, 2000). The coded statement percentages indicate that Southern MS may have functioned as a CoP on a more advanced level than Northern MS; Southern MS was able to spend time in PLC meetings on each of the three characteristics of social learning equally and Northern MS seems most focused on enterprise and repertoire. Wenger (2000) explains that the three characteristics rely on each other; "Without the learning energy of those who take initiative, the community becomes stagnant. Without strong relationships of belonging, it is torn apart. And without the ability to reflect, it becomes hostage to its own history" (p. 230). These types of positive team interactions are known to create higher team member motivation and commitment as well as improving workplace outcomes (Basford, Offermann, & Wirtz, 2012). These conclusions also resonate what has previously been found in the PLC literature, in other settings; PLCs have a higher success rate when interpersonal relationships are strong (Robertson & Jones, 2013).
Tasks That Were Carried Out in Preparation for STEM Club Meetings

The findings from this study suggest that during PLC meetings, the T-Coaches were most likely reviewing the club agendas, content coaching each other, practicing club activities, and organizing materials along with many other tasks associated with preparing for student STEM Club meetings (see Table 6.1). Additionally, T-Coaches took time during the PLC meeting to discuss logistics for the residential on campus stay, which was necessary, but did not help prepare them for student STEM Club meetings.

Table 6.1

<table>
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<th>PLC Meeting Team Interaction Comparison</th>
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<td>Reviewing Agendas</td>
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<td>Content Coaching</td>
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<td>182</td>
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<td>Practicing Club Activities</td>
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<td>161</td>
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<td>T-Coach Interest</td>
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<td>Club Structure</td>
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<td>Pedagogy</td>
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<td>42</td>
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<td>Organizing Materials</td>
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<tr>
<td>Creating Supplemental Materials</td>
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<tr>
<td>Professional Speaker</td>
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<tr>
<td>Completing the Checklist</td>
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<td>24</td>
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<tr>
<td>Assigning Roles</td>
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<td>24</td>
</tr>
<tr>
<td>Playful Teasing</td>
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<tr>
<td>Personal/Social Dialogue</td>
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<td>86</td>
</tr>
<tr>
<td>Residential Weekend</td>
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<td>14</td>
</tr>
<tr>
<td>Other</td>
<td>57</td>
<td>171</td>
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</table>

*Total Percent over 100 as some statements were double coded

The some of the PLC activities also align with what was reported by Miranda and Damico (2015) and Fulton and Britton (2011) from their studies on PLCs. Miranda and Damico reported that the PLC helped teachers developed further in their understanding of
reform-based practices and modifying their beliefs about teaching and learning. Fulton and Britton (2011) found that the PLC they studied advanced teachers' content preparedness and attitudes toward teaching methods. In the current study, activities in both of the schools’ PLC were found that would suggest similar activities were taking place in their PLC meetings (content coaching, discussions on pedagogy and T-Coaches practicing club activities). Robertson and Jones (2013) reported success in their PLC study was associated with teacher's discussions on strategies for lesson planning and sharing resources, similar (in this study) to reviewing the agendas, creating supplemental materials, and organizing materials. Mizzi (2013) reported that PLCs are also important when teachers are teaching outside of their content area, which was the case for many of the T-Coaches in this study. Indeed, some of the material was involved new technologies that were new to all of the teachers, regardless of their content areas (e.g., Raspberry Pi, Pandemic 2). Mizzi suggests that teachers who need help should seek advice from subject specialists, which was frequently found in this study, particularly at Northern MS, with T-Coaches who had attended TPD content coaching team members during PLC meetings.

These interactions show that the T-Coach teams took part in similar activities that other research studies have reported taking place in a PLC such as opportunities to enhance teaching quality, mutual communication and a rich understanding of teaching practice (Park & So, 2014).

The findings of this study provide evidence to suggest that the use of a PLC to support the implementation of a STEM after-school club is most successful when the team demonstrates the social learning characteristics of CoP at high levels and equally. While meeting as a team, the schools completed many tasks that helped them prepare for the club
meetings (reviewing the club agendas, content coaching each other, practicing club activities, and organizing materials), building their community of practice in the process. Finally, the scores on the DoS observation tool suggest that the club with a higher functioning CoP within the PLC facilitates a more successful STEM Club.

Some activities observed during PLC meetings did not seem to help prepare the T-Coaches for the student STEM Club meeting such as playful teasing, social/personal dialogue and what was categorized as 'other' (i.e., discussing the school science fair, discussing different teaching strategies, venting about the regular school day, and research tasks requested by the research team). Allen, Yoerger, Lehman-Willenbrock, and Jones (2009) would consider these as counterproductive meeting behaviors. They surveyed 443 employees from various professions that regularly attend meetings and reported that counterproductive behaviors include engaging in irrelevant discussion, complaining about other attendees, arriving to the meeting late, and disruptive behaviors. They claim that these behaviors negatively impact the meeting and coworker relationships. They conclude that meeting leaders should seek ways to reduce these counterproductive behaviors and promote good meeting processes (Allen et al., 2009). Interestingly, this study did not find these behaviors to negatively impact the PLC meeting and in fact, they seemed to strengthen coworkers’ relationships by forming bonds and trust.

*Dimensions of Success Scores*

DoS ratings were used in both of the findings chapters. Averages for both schools over six club meetings were used as descriptive outcomes. In the first findings chapter, Chapter Four, the ratings of club success were compared between the two cases to better understand if certain T-Coach team interactions had higher functioning PLCs (based on
CoP). The DoS was used in the second findings chapter, Chapter Five, to analyze which dimensions of success the schools performed well in, and which dimensions were less prevalent. The DoS was also used to analyze if T-Coach behaviors and beliefs were related to more desirable DoS ratings (score of 3 or 4; 1-Evidence Absent; 2-Inconsistent Evidence; 3-Reasonable Evidence; 4-Compelling Evidence).

Although both schools received access to identical TPD, club materials, and PLC checklists, the two schools differed in their club success based on the DoS observation tool. Northern MS met desirable rankings for seven out of twelve dimensions (58%), which translated to achieving desirable ratings for two out of the four domains. Southern MS proved more “successful,” achieving desirable DoS ratings in eleven out of twelve dimensions (92%), translating to all four domains.

First, the ways in which the DoS scores were similar will be discussed. The two clubs both averaged desirable ratings in Space Utilization, showing both schools were able to provide a space adequate for the STEM activity that was both informal and free of distractions. Both schools averaged desirable scores in the Materials dimension suggesting they were able to provide materials that were appealing and appropriate for the students. The schools also had desirable ratings in Inquiry, which indicates that the students were able to practice STEM in authentic ways. The two STEM clubs were also able to maintain a desirable rating in Relationships showing they created a positive environment that was warm and welcoming and all roles were interacting well (student-student, T-Coach-T-Coach, and Student-T-Coach). The last dimension in which the STEM Clubs were similar in was Relevance, which indicates that the T-Coaches made connections to a broader context and
that students were involved in discussions of the relevance of what they were doing to their lives.

These results align with findings from previous studies that have used the DoS observation tool (Martinez et al., 2014), providing evidence that these two clubs are scoring similar DoS scores to other STEM programs that have been evaluated. However, one area that does not align with previous findings is the Space Utilization score. This dimension was usually a low score in other studies but the two study schools, in this study, were able to score desirable scores consistently. Martinez et al. (2014) explained that in their study many of the spaces used for the STEM program were cramped or not conducive to the STEM activities whereas this study's schools held their STEM Clubs in an informal environment that was conductive to the STEM activity and free of distractions.

The dimensions that highlighted the most variation between schools were Purposeful Activities, Reflection, and STEM Content Learning. In reference to Purposeful Activities, Northern MS tended to have more ‘down time’ when students were not always focused on activities that would bring them closer to the learning goal (i.e., playing games on the Raspberry Pi rather than doing the circuit board connection as intended), which resulted in a rating of a two for that club meeting. Southern MS kept students busy with activities that would continue to bring them closer to the learning goal showing compelling evidence, which resulted in their score of a four in the Purposeful Activities dimension. In regard to Reflection, Northern MS did not regularly prompt students to reflect; they had inconsistent evidence for this practice, which resulted in their score of a two. Southern MS continued to ask questions before and after the activities, showing compelling evidence for that dimension, which resulted in a higher score of four. Southern MS also had a higher score in
STEM Content Learning, as they tended to use specific terms associated with equipment (i.e., HDMI cord, Ethernet port) whereas Northern MS received a lower score with superficial terms (i.e., cord, wire).

Martinez et al. (2014) reported most summer programs they observed achieved desirable ratings on purposeful activities (75% of the time desirable) which is different than NMS (50% of the time desirable). Martinez et al. also observed lower ratings in reflection (31% desirable) and STEM content learning (44% desirable) which is in line with NMS (16%, 50%) but different than SMS (100%, 83%).

These observations indicate that the two schools were different in their student club facilitation and therefore, differed in the nature and degree of some of their club successes, as measured with DoS scores. This difference could be a result of the types of interactions they take part in during PLC meetings and their ability to function as a PLC according to CoP. From the CoP analysis, Southern MS's team PLC functions at a higher level than Northern MS. In addition, Southern MS's team is facilitating a more successful STEM Club according to the DoS ratings. This difference suggests there is a relationship between PLC functioning and STEM Club facilitation. According to CoP, when a team works together for a common goal, the team should have social learning characteristics such as (enterprise- learning energy; repertoire- self-awareness; and mutuality- social capital) (Wenger, 2000). The team that had a more equivalent and higher level of these three was also the club that had higher ratings of success (Southern MS). Previous research has also found that successful PLC implementation resulted in higher outcomes (student or program) (Hardinger, 2013; Owen, 2015; Ronfeldt et al., 2015).
The findings of this study provide evidence to suggest that the use of a PLC to support the implementation of a STEM after-school club was most successful when the team demonstrated the social learning characteristics of CoP equally. While meeting as a team, the schools completed many tasks that helped them prepare for the club meetings (reviewing the club agendas, content coaching each other, practicing club activities, and organizing materials). Finally, the scores on the DoS observation tool suggest that the club with a higher functioning CoP within their PLC facilitates a more successful STEM Club.

*T- Coaches' Beliefs*

Both sets of T-Coaches believed that student *Participation* and *Relationships* were important to STEM Club success. However, on average one T-Coach team believed the Engagement with STEM and Purposeful Activities dimensions were most important. Neither STEM Club T-Coach team believed *Space Utilization* was important. These results indicate that T-Coaches believed that student involvement and access to the activities should be a high priority. T-Coaches value the interpersonal relationships they foster with students and believe that it is a key to student learning. These results also show that one group of T-Coaches places high value on providing students opportunities to engage with STEM in authentic ways and that all activities used are intended to move students closer to the STEM learning goal.

Upon further analysis, it was found that each T-Coach ranked the dimensions differently; no two card sort arrangements were the same. These results show that for each dimension, at least one T-Coach ranked it as a top priority. However, these results did not explain what was happening during club meetings as not all dimensions achieved desirable ratings.
T-Coaches' Beliefs Compared to Observed Practices

Results from this study indicate that when it comes to STEM program success the whole of the team is better than the sum of its parts. Each team member valued different aspects of the STEM Club and with this dynamic, no DoS dimension is left unvalued. Each member ranked the dimensions of success cards according to his or her own beliefs, which created a net that if each member of the team was prepared and present, no dimension would be lost.

The theoretical framework, Social Cognitive Theory, informed the findings of this study. As Bandura posited of human behavior, the T-Coaches behaviors at STEM Club meetings were a result of the individual's personal, environmental, and behavioral factors. In an effort to explain how the T-Coaches could believe that a dimension was important and yet fail to achieve desirable DoS ratings, the researcher identified five scenarios from the data analysis (see full description in Findings section of this paper). Not only do the scenarios align with SCT, these results support the existing literature regarding teachers' beliefs and the theory that beliefs teachers hold can influence their practices (Addy & Blanchard, 2010; Blanchard et al., 2016; Blanchard et al., 2009; Capps & Crawford, 2013; De Vries et al., 2013; Kunter et al., 2013; Lotter et al., 2013; Lumpe et al., 2012; Southerland et al., 2011; Wallace & Kang, 2004). These results are also correlated with prior research indicating teacher beliefs are associated with how teachers decide how to teach (i.e. low inquiry beliefs, low inquiry observed in lessons) (Capps & Crawford, 2013; Lotter et al., 2013; Wallace & Kang, 2004).

In the Full Preparation scenario, the T-Coaches believed a certain dimension to be important (personal factors), they attended the TPD and PLC meetings (behavioral factors),
within a team setting (environmental factors), which prepared them to act on their beliefs (behaviors observed) when they attended the student STEM Club meeting with at least one other T-Coach who believed the same, resulting in a desirable DoS rating.

In the PLC Only Preparation scenario, the T-Coaches believed a certain dimension to be important (personal factors), they attended PLC meeting (behavioral factors), within a team dynamic (environmental factors) which prepared them to act on their beliefs (behavioral outcomes) when they attended the student STEM Club meeting with at least one other T-Coach who believed the same, resulting in a desirable DoS rating.

In the No TPD or PLC Preparation scenario, the T-Coaches believed a certain dimension to be important (personal factors), they did not attend the TPD or PLC meeting (behavioral factors), within a team setting (environmental factors), leaving them unable to act on their beliefs (behavioral outcomes) even if they attended the student STEM Club meeting with one other T-Coach who believed the same, causing an undesirable DoS rating.

In the No PLC Preparation scenario, the T-Coaches believed a certain dimension to be important (personal factors), they did attended the TPD but did not attend the PLC meeting or a PLC meeting was not held (behavioral factors), in the team setting (environmental factors), which allowed too much time in between training and practice, leaving them unable to act on their beliefs (behavioral outcomes) even if they attended the student STEM Club meeting with one other T-Coach who believed the same, causing in a undesirable DoS rating.

In the Unvalued Preparation scenario, the T-Coaches did not believe a certain dimension to be important (personal factors), they may or may not have attended the TPD or PLC meeting (behavioral factors), or in the team setting (environmental factors), they did not
lead the student STEM Club meeting in a way that would meet the dimension criteria (behavioral outcomes), causing an undesirable DoS rating.

These results indicate that T-Coach behavior at STEM Clubs was influenced by the factors Bandura presented in the Reciprocal Determinism model of Social Cognitive Theory. These T-Coaches displayed differing behaviors at STEM Clubs depending on their personal, environmental, and behavioral factors. The environmental influence has also been identified as influential to teachers' beliefs in prior research (Driel et al., 2001; Zhang & Liu, 2014). Evidence for this claim can be found in the five scenarios identified from the findings from two separate STEM Club T-Coach teams. It was not sufficient that T-Coaches valued a certain dimension; the dimension would not be met on the DoS scale if the T-Coach did not have the training and preparation to meaningful act on their beliefs. It was found that at least two T-Coaches who value a certain dimension are needed to ensure that dimension would be met on the DoS rating which shows the significance of the team aspect in this setting.
CHAPTER SEVEN
Conclusions and Recommendations

Finding from this study reveal that Teacher-Coaches in both case study STEM Clubs had communities of practice, with evidence of social learning characteristics (enterprise, repertoire, and mutuality) during PLCs. Results from this study also indicate that the two STEM Clubs were performing fairly well, according to the DoS. Card sort results provided evidence that T-Coaches’ beliefs differed, and five scenarios were identified that flowed from these beliefs and the participation of the T-Coaches of TPD and/or PLCs, impacting STEM club success. The findings from this study suggest the following conclusions:

- Implementing a PLC in the context of a STEM after-school program assisted T-Coaches in STEM Club facilitation.
- Levels of social functioning could be examined through communication of the T-Coaches during pre-club PLC meetings.
- T-Coach teams who exemplified higher levels of all of the social characteristics of a community of practice (enterprise, repertoire, and mutuality) also had higher ratings on dimensions of STEM Club success, based on the DoS ratings.
- The personal relationships of the team members mattered in terms of more visibly positive STEM Club experiences and more desirable team outcomes.
- Attendance at TPD was a critical component to success of the PLC, and then the STEM Club.
- The CoP framework and the DoS tool were useful for examining how a STEM Club PLC was functioning, and the resulting success of the clubs.
• The results from this study indicate that it takes two T-Coaches who both valued and were prepared for the STEM Club for the program to attain an acceptable DoS score.

• It was also not sufficient that T-Coaches valued a certain dimension; the dimension would not be met on the DoS scale if the T-Coaches did not have the training and preparation to meaningful act on their beliefs.

• As a team, all DoS dimensions were valued and believed to be important for STEM Club success. It was not essential, with a team of teachers, that the DoS dimensions were equally valued in order to be implemented in STEM Clubs. A range of the perceived values of various dimensions can work if there are multiple STEM Club leaders.

• Individual perceptions of the importance of different dimensions of STEM Clubs can be expected to differ from one another, even between members of the same team.

• If only one T-Coach leads the STEM Club the dimensions he or she values the most may be the only ones prioritized.

• The STEM Club DoS scores were consistent with what other studies have found when using the DoS to measure STEM out of school program success. The schools in this study scored higher in the Space Utilization dimension than the other published studies reported.

• TPD and PLC meeting were effective at preparing Teachers to lead STEM Club meetings. If a TPD was missed, then meeting prior to the club was essential to learn STEM content and to plan.

• T-Coaches were influenced by personal, environmental, and behavioral factors (Bandura, 1986) and this was further explained in the five scenarios identified from
the findings from two separate STEM Club T-Coach teams (Full, PLC Only, No TPD or PLC, No PLC, and Unvalued Preparation).

Limitations

There were several limitations for the study. Overall, the context was an after-school STEM Club; a novel setting for PLC implementation and the sample size for this study was small. The teachers recruited were not taken from a single content area or grade level and they self-selected to participate. The teachers who participated were also compensated by the grant project for attendance at TPC, PLC meetings, and STEM Club meetings. While the researcher did not directly facilitate the PLC meetings, the researcher did lead the professional development when teachers were trained, created the checklists for the PLC meetings, observed all of the club meetings throughout the four schools during the study, and interviewed teachers. Thus, the researcher was not primarily responsible for what took place during the PLC meetings or STEM Club meetings in the four schools, as she did not train the teachers on the DoS. The PLC meetings were audio recorded and not video recorded which did not allow for analysis of physical behaviors or body language. The schools involved in the study have a high minority, high poverty student populations located in rural areas.

Recommendations

From this study, it is recommended that when stakeholders are initiating a STEM after-school program a PLC should be implemented to assist T-Coaches in STEM Club facilitation. It is also recommended that using a team dynamic such as a PLC (consisting of at least two but ideally more members) can ensure that gaps between what members value are met. Using a team of T-Coaches instead of an individual can decrease dimensions that are connected to STEM Club success (Papazian et al., 2013). It is also recommended that to
fully prepare to implement a new initiative, T-Coaches should be present at TPD and PLC meetings. If the T-Coach cannot be present at TPD, attending a PLC meeting can make up the preparation deficiency. During the PLC meetings, the T-Coaches who did attend TPD can train and coach the ones who did not. It is not recommended to attend TPD without a pre-club PLC meeting; with time, members can forget what they were taught and the program could suffer. The levels of social functioning should be examined through communication of the T-Coaches during pre-club PLC meetings and if the social functioning is weak, actions such as team building measures should be taken, perhaps during TPD. It is also suggested that all of the social characteristics of a community of practice (enterprise, repertoire, and mutuality) be stressed to the team members; as seen in this study, higher levels of these as well as an equal balance can positively impact program outcomes. It is also suggested that personal relationships of team members be encouraged during TPD, as these seemed to matter in terms of more visibly positive STEM Club experiences and more desirable team outcomes. It should be stressed to team members to attend TPD as it was seen as a critical component to success of the PLC, and then the STEM Club. If intending to assess how individuals collaborate to facilitate a STEM program, CoP framework and the DoS tool could both be useful for examining how a STEM program PLC was functioning, and the resulting success of the program.

Future work in this area could include survey creation for how the team members perceive their team dynamics. This data could provide more perspective into the team's interpersonal relationships, and inform those who are planning and implementing TPD to enhance positive interactions, or could be shared self-assessments between team members. Future work could also include working with teacher teams who are struggling or could use
some guidance in their team development. An intervention could be facilitated for team members are pre and post data could be collected to see if perceptions had changed. Future work can also include asking the teachers/club leaders about which dimensions they believe are effective and which are not. Work could also be done to teach those who are carrying out STEM clubs about the DoS, and using Pre/post observations, study the impact on the effectiveness of the STEM Clubs. It might be beneficial to investigate leadership roles within the PLC teams and see how those shape outcomes. Future work could also include observing a program before and after implementation of a PLC to assess the influence the PLC has on outcomes (with other variables controlled- TPD attendance). Testing of students’ content knowledge before and after the STEM program might reveal outcome differences between higher and lower performing programs.
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APPENDIX
Appendix A: Dimensions of Success Documents

An Introductory Guide to the Dimensions of Success (DoS) Observation Tool

What is DoS?
The Dimensions of Success observation tool, or DoS, pinpoints twelve indicators of STEM program quality in out-of-school time. It was developed and studied with funding from the National Science Foundation (NSF) by the Program in Education, Afterschool and Resiliency (PEAR), along with partners at Educational Testing Service (ETS) and Project Liftoff. The DoS tool focuses on understanding the quality of a STEM activity in an out-of-school time learning environment and includes an explanation of each dimension and its key indicators, as well as a 4-level rubric with descriptions of increasing quality (see p.4 for sample rubric).

How can you use DoS?
DoS was designed to be a self-assessment observation tool for STEM program administrators and staff. It can also be used by external evaluators or funders to track quality in programs over time or quality across a city or a state.

To use DoS, you must be trained and certified (see section below). After certification, you can use the tool as often as you would like to measure the quality of STEM activities.

Observation notes and scores are entered online, and PEAR provides reports that show trends over time and across particular dimensions.

When used for program quality improvement, we suggest debriefing the activities or lessons with your ratings with staff, and having them join in the process of pinpointing strengths, weaknesses, and next steps for improving quality.
What are the dimensions?

DoS measures twelve dimensions that fall in 4 broad domains: Features of the Learning Environment, Activity Engagement, STEM Knowledge and Practices, and Youth Development in STEM.

The first three dimensions look at features of the learning environment that make it suitable for STEM programming (e.g., do kids have room to explore and move freely, are the materials exciting and appropriate for the topic, is time used wisely and is everything prepared ahead of time?).

The second three dimensions look at how the activity engages students: for example, they measure whether or not all students are getting opportunities to participate, whether they are doing activities that are engaging them with STEM concepts or something unrelated, and whether or not the activities are hands-on, and designed to support students to think for themselves versus being given the answer.

The next domain looks at how the informal STEM activities are helping students understand STEM concepts, make connections, and participate in the inquiry practices that STEM professionals use (e.g., collecting data, using scientific models, building explanations, etc.).

Finally, the last domain assesses the student-facilitator and student-student interactions and how they encourage or discourage participation in STEM activities, whether or not the activities make STEM relevant and meaningful to students’ everyday lives, and the experiences. Together, these twelve dimensions capture key components of a STEM activity in an informal afterschool or summer program.
Planning to use DoS

Step 1: What are your goals for assessment/evaluation?
- Do you want to help individual afterschool science program sites pinpoint their strengths and weaknesses?
- Do you want data about entire programs (e.g., Boys and Girls Clubs or YMCA's)
- Do you want external evaluators to use DoS to report quality across the state?

Step 2: Who will be using DoS and how often?
- The staff at each site will observe each other’s lessons
- The staff leaders at each site will observe each unit twice
- The program leaders will observe each site twice
- State representatives from STEM board will visit each site in Fall and Winter

Step 3: What will you do with the data?
- Ratings will be discussed internally with staff and then next steps will be outlined
- Quarterly Reports (created by PEAR) will be distributed to stakeholders; these reports show a site or program’s scores on each dimension four times a year.
- By Module Reports—show scores on each dimension for each type of module or curricular unit (can be aggregated across sites or just for a single site)
- Regional or Statewide Trend Report—aggregates data across all programs and shows scores on dimensions over a year; or divided by region; or divided by type of program (e.g., school-based program, museum-sponsored program, community-center program)
**How do you get certified to use DoS?**
To use DoS, a potential observer must complete a certification process. First, he/she must attend a 2-day training (in-person or online) to learn how to define and observe quality in each dimension. Next, potential observers must complete a set of video simulation exercises to practice their understanding of the tool. PEAR will then review their ratings and evidence from these exercises, and will provide customized feedback at a one-hour calibration session (phone conference). At this session, PEAR trainers will help to address any questions and to provide additional examples that might be needed to clarify use of the tool. Finally, potential observers will then arrange to practice using DoS in the field at afterschool sites in their local area. This step allows them to use the tool in the field to incorporate the feedback they received on the video simulations. Upon successful completion of all these requirements, observers will be DoS certified for 2 years and can use the tool as often as they would like during that period. After 2 years, there are opportunities for re-certification if needed.

For pricing and registration for an upcoming training, please contact Dr. Ashima Shah at ashah@mclean.harvard.edu.

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**How long does the certification process take?**
We can support trainees to complete the steps as fast or slow as they would like, but we encourage each trainee to commit to completing the steps within 2 months. The longer one waits, the harder it is to remember what is learned in each step of the process. We have had trainees finish all steps in less than 2 weeks—so you can go as fast as you would like—just let us know, so we can support you and make sure you get feedback at the right times. It is up to your own organization and leaders to set and maintain deadlines—we provide guidelines, but can not enforce deadlines as we know many of our trainees have other jobs/commitments.
Date:

Activity Name:

Facilitator(s) Name:

Location:
Thank you for participation in a DoS observation.

After a live observation, your observer will provide DoS ratings for each dimension (see table below). The DoS observer will then complete the rest of this report to highlight the strengths of your activity and to suggest possible areas for improvement.

The Dimensions of Success rating scale is from 1-4, with 4 generally representing characteristics of high quality. However, please note that there are many subtleties within the ratings, and sometimes a 1 or 2 may be appropriate for a particular activity and only be problematic if seen as a trend over several observations. Observers are trained to understand these subtleties and the feedback provided in this document will focus on the areas that are most important to focus on for the activity observed. Please note, it is rare that an activity scores 4 on every dimension. The tool helps to push even strong activities to be stronger.

On the following pages, your observer(s) has provided notes based on what he/she identified as the most important Dimensions relevant to your activity.

At the end of this form, you will find an overview of each dimension.

Tips to guide you as you plan for your next activity are included in a separate attachment.

Contact Dr. Ashima Shah (ashah@mclean.harvard.edu) at PEAR if you have clarifying questions, are interested in learning more about the DoS observation tool, or would like to learn more about your ratings.

Thanks for your commitment to high-quality STEM programming!

Overall ratings for today's observation:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
<td>▼</td>
</tr>
<tr>
<td>Materials</td>
<td>▼</td>
</tr>
<tr>
<td>Space Utilization</td>
<td>▼</td>
</tr>
<tr>
<td>Participation</td>
<td>▼</td>
</tr>
<tr>
<td>Purpose Activities</td>
<td>▼</td>
</tr>
<tr>
<td>Engagement with STEM</td>
<td>▼</td>
</tr>
<tr>
<td>Inquiry</td>
<td>▼</td>
</tr>
<tr>
<td>STEM Content Learning</td>
<td>▼</td>
</tr>
<tr>
<td>Reflection</td>
<td>▼</td>
</tr>
<tr>
<td>Relationships</td>
<td>▼</td>
</tr>
<tr>
<td>Relevance</td>
<td>▼</td>
</tr>
<tr>
<td>Youth Voice</td>
<td>▼</td>
</tr>
</tbody>
</table>
Activity Strengths:

- Dimension #1:  

- Dimension #2:  

- Dimension #3:  

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Areas for Improvement:

- **Dimension #1:**

  Suggestions include:

- **Dimension #2:**

  Suggestions include:

- **Dimension #3:**

  Suggestions include:

Additional Notes:
Overview of the Dimensions of Success (DoS) Framework for STEM Program Quality

Each “dimension” in the Dimensions of Success tool asks the observer to consider a series of questions related to quality STEM teaching in youth development settings.

Central questions for each Dimension are listed here. If you would like further information about the Dimensions, explore the DoS Planning Tool at www.pearweb.org/tools/dos.html#planningtool or call 617-484-0466.

Organization
- Is there evidence that the facilitator prepared the materials and the space for this activity period ahead of time? Or is activity time lost while the facilitator gets materials or sets up the activity?
- Is there enough time for each part of the activity? Or is there too much time (time left over) or not enough time (a rush to finish or unable to complete)?
- If something unexpected happens, is the facilitator able to adjust so that the activity is still carried out smoothly?

Materials
- Are these materials appealing to the students? Do the students want to use these materials, or are they bored or put off by them?
- Are the materials appropriate for the students? Are they age-appropriate? Are they too difficult or too easy? Is it safe for these students to be using these materials?
- Are the materials appropriate for the STEM learning goal? Are these the right materials for this activity, and can these materials be used to get students to the learning goal? Are there any errors or inaccuracies in informational materials? (Note: Whether or not the materials are used well is not judged here – only if they could be used for the learning goal.)

Space Utilization
- Is the space being used informally? Are students able to work in groups, move around, investigate, etc? Or is the space being used in a formal lecture-style format? (Note: Most activities will have an introductory portion with the facilitator explaining an activity, but the majority of the activity should not be lecture style.)
- Is the space appropriate for this particular type of activity? Do students have space to complete the activity? For instance, if the activity involves running around to different stations, is the space large enough to accommodate that or are kids tripping over desks, chairs, and each other?
• Are there any distractions in the space that impact student learning?

Participation
• Do all students have equal access to the activity? Can all students reach, see, read, hear, or otherwise access the activity’s information and materials?
• Are all students included and encouraged to participate? Or is a subgroup excluded or ignored – i.e. girls, boys, a racial/ethnic group, etc?
• Do students who choose not to participate get prompted, invited, or welcomed to the activity? Or are they left to “opt out” without encouragement?

Purposeful Activities
• Is there an identifiable STEM learning goal for the activity? When activities involve art, games, etc, are these activities supporting STEM learning, or do they lose or lack a connection to STEM?
• How does each part of the activity move students toward that goal? Is each part of the activity helping students to understand and learn, or do some parts only somewhat relate to the STEM learning goal?
• Do students understand what they are doing and why? What evidence shows that students know the purpose or meaning behind what they’re doing?

Engagement with STEM
• Does the activity provide opportunities for students to explore ideas in a hands-on way? For example, are students planting seeds, manipulating a physical model, programming a robot, playing an interactive game about ecosystems, etc. versus reading a worksheet, watching a movie, or listening to facilitator explanations?
• Do the hands-on experiences also allow students to do the cognitive thinking or are they just “going through the motions?”
STEM Content Learning
- Are there any errors in the STEM content? Does the facilitator present information that is correct?
- Are the students learning concepts, ideas and connections between ideas, or is the learning limited to isolated details such as vocabulary words or a list of facts?
- Do students comments and questions indicate they are going beyond memorizing and instead, starting to explain and make sense of the intended STEM learning goal?

Inquiry
- Are STEM practices present in the activity? Is there evidence of observing, making hypotheses, collecting data, analyzing data, making models, testing models, designing and redesigning, using STEM tools, etc?
- Do students get to engage in STEM practices themselves or are they watching someone else do them?
- How authentic are the students’ experiences? Do they experience the work that STEM professionals do, or are they following rote instructions without any opportunity for true “discovery”?

Reflection
- Is there evidence that the facilitator provides prompts for reflection? Do the students complete each phase of the activity and then abruptly “clean-up” or are there opportunities for to think and talk about what they learned?
- Are the students engaging in quality reflection? Or are they providing simple responses like, “I got the same answer” or “my experiment worked”?
Relationships
- Are there any negative or concerning interactions in the learning environment (e.g., sarcasm, yelling, bullying)?
- What efforts are made to create and maintain a warm, encouraging, and supportive environment? Does the facilitator address potentially difficult situations and help students resolve conflicts?
- Does the facilitator’s relationship with the students support STEM learning? Do the students show signs of wanting to share ideas with the facilitator, and vice versa? Do positive relationships help to draw in students who are reluctant to engage with the activity?

Relevance
- Does the facilitator relate the activity to a broader context in the students’ lives? Is this a single comment that is stated once and not again throughout the activity, or does the facilitator provide an elaborated description, or several examples, of how this content could be applied to the wider world?
- Do the students make comments that indicate that they are relating the activity to a broader context? Do students seem to provide examples from their own knowledge or lives, or is it only the facilitator making connections?

Youth Voice
- Does the activity encourage students to share their ideas, concerns, and queries? Do they have opportunities to talk, debate, or question?
- Are there opportunities for students to take leadership over the direction of the activity, or is the activity facilitator-driven without any flexibility or open-endedness?
- Can students make important and meaningful choices? Or are students left making no choices, or superficial choices such as where to sit, what color paper they can use, etc!
**Appendix B: Example Pre Club Check List**

**Physiology - Meeting #9 PRE-CLUB CHECKLIST**

Date: ____________________________

Teachers who attended club preparation meeting:

<table>
<thead>
<tr>
<th>Needed Preparation</th>
<th>Person / People Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snack is purchased and ready at the beginning of club</td>
<td></td>
</tr>
<tr>
<td>Students will watch a short videos</td>
<td></td>
</tr>
<tr>
<td><strong>Before the Club:</strong> Have laptop cart and projector (or SMART Board) set up with videos loaded, making sure videos are working correctly.</td>
<td></td>
</tr>
<tr>
<td><strong>Websites that will need to be accessible:</strong></td>
<td></td>
</tr>
<tr>
<td><a href="https://www.youtube.com/watch?v=ZsPsKLjw-SI">https://www.youtube.com/watch?v=ZsPsKLjw-SI</a></td>
<td></td>
</tr>
<tr>
<td><a href="https://www.youtube.com/watch?v=fWgU0J0F_hE">https://www.youtube.com/watch?v=fWgU0J0F_hE</a></td>
<td></td>
</tr>
<tr>
<td><a href="https://www.youtube.com/watch?v=uBrF5VfxrmM">https://www.youtube.com/watch?v=uBrF5VfxrmM</a></td>
<td></td>
</tr>
<tr>
<td><a href="https://www.youtube.com/watch?v=04yGUJTCAzI">https://www.youtube.com/watch?v=04yGUJTCAzI</a></td>
<td></td>
</tr>
<tr>
<td><a href="https://www.youtube.com/watch?v=-_XiAbAe7t4">https://www.youtube.com/watch?v=-_XiAbAe7t4</a></td>
<td></td>
</tr>
<tr>
<td>Students will begin learning about natural selection</td>
<td></td>
</tr>
<tr>
<td><strong>Before the Club:</strong> You will need to have all the materials ready for the club meeting</td>
<td></td>
</tr>
<tr>
<td>● Vertical jump measure fixed to wall (1 per group/class)</td>
<td></td>
</tr>
<tr>
<td>● Scale to weigh (1 per class)</td>
<td></td>
</tr>
<tr>
<td>● Flexible tape measure (1 per group)</td>
<td></td>
</tr>
<tr>
<td>● Paper</td>
<td></td>
</tr>
<tr>
<td>● Pencil</td>
<td></td>
</tr>
<tr>
<td>● Calculators (1 per group)</td>
<td></td>
</tr>
<tr>
<td>Review the activities and how to facilitate them.</td>
<td></td>
</tr>
<tr>
<td>Review the agendas together and be sure that everyone knows what will happen when and how the student activities will flow during the meeting</td>
<td></td>
</tr>
<tr>
<td>Review the content that should be covered in the activity—someone who is comfortable with physiology and predictive modeling.</td>
<td></td>
</tr>
<tr>
<td>If there is a professional STEM speaker scheduled to speak at your school make sure Google Hangout™ works as a communication tool at your school and that there is a computer/projector set-up and ready to be used</td>
<td></td>
</tr>
</tbody>
</table>

*Please complete this in the Google Form™. Thanks!*
Appendix C: Teacher Belief Interview Survey Questions
TBI - Teacher STEM CC

Q1 Today's Date:

Q2 Your FIRST name:

Q3 Your LAST name

Q4 Your School's Name:

Q5 How do you maximize student learning in your classroom?

Q6 How do you describe your role as a teacher?

Q7 How do you know when your students understand a concept?

Q8 In what ways do you manipulate the educational environment to maximize student understanding?

Q9 In the public school setting, how do you decide what to teach or what not to teach?

Q10 How do you decide when to move on to a new topic in your class?

Q11 How do your students learn science/math/technology/other best?

Q12 How do you know when learning is occurring in your classroom?

Q13 What do you believe are your main strengths as a teacher?

Q14 In what areas would you like to improve as a teacher?
Appendix D: Teacher Demographic Survey

STEM CC Teacher Leader Questionnaire

Thank you for taking the time today to complete the teacher leader questionnaire. When finished, please remember to return this questionnaire and consent form to the researchers before leaving today!

Your Name:

Are you a:
☐ Female Teacher
☐ Male teacher

Your School Name:

How long have you been involved in STEM CC?

How long have you been a teacher?

How long have you been a teaching at your current school?

What is your content area?

What is your race/ethnicity?

What is your highest degree earned?
☐ Bachelors
☐ Masters
☐ Advanced Certification
☐ Doctoral
Appendix E: Pre-Club Audio Recording Instructions

Pre-Club Audio Recording

If/when you meet for your pre-club meeting, please place this recorder in a central location between attendees.

The recorders are powered on using the switch on the right side: Pull the switch toward power side and hold for a moment to turn the recorder on.

Once the recorder is on, press the record button twice. If you press it once the light will blink but will not be recording, if the red light is on without blinking, audio is being recorded.

Once the meeting is finished: press the Stop button on the recorder and pull the switch on the right side toward power to turn off the recorder. Keep for the next meeting. Thank you!
Appendix F: Card Sort Protocol and Cards

Card Sort activity for DoS

1. Okay, I’d like to have you complete a card sort. Each card describes a dimension that we believe to contribute to STEM out-of-school time program success. I want you to take the cards and sort them. If you believe some are more important place on the left and if they are less important on the right. It is okay if some that have equal importance. While you are doing this, I want you to talk through your process of choosing each card’s placement, like a think aloud.

   a. Prompt- why did you place that card there? Or why did you move that card?

<table>
<thead>
<tr>
<th>Organization</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials are ready</td>
<td></td>
</tr>
<tr>
<td>Time well planned</td>
<td></td>
</tr>
<tr>
<td>Have a back up plan</td>
<td></td>
</tr>
<tr>
<td>Materials are appealing to the youth</td>
<td></td>
</tr>
<tr>
<td>Materials are appropriate for the youth</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Space Utilization</th>
<th>Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informal setting</td>
<td></td>
</tr>
<tr>
<td>Sufficient space</td>
<td></td>
</tr>
<tr>
<td>Few distractions</td>
<td></td>
</tr>
<tr>
<td>Students have access to the activity</td>
<td></td>
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<tr>
<td>Students stay focused</td>
<td></td>
</tr>
<tr>
<td>Equal involvement between groups</td>
<td></td>
</tr>
</tbody>
</table>
Appendix G: Example STEM Club Agenda

Introduction to Raspberry Pi - Meeting #4

Agenda (May be subject to change slightly)

<table>
<thead>
<tr>
<th>Topics (Meeting # 4)</th>
<th>Agenda/Activities</th>
<th>Time Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Split Students into Smallest Groups Possible Based on Amount of Raspberry Pi Computers (Ideally 2 or less per group) and each group needs a monitor as well</td>
<td>5 min (or less)</td>
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<tr>
<td></td>
<td>3. Give Each Group Raspberry Pi and Student Packet</td>
<td>5 min</td>
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<tr>
<td></td>
<td>4. Facilitate Raspberry Pi Introductory Activity (attached)</td>
<td>60 min</td>
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<tr>
<td></td>
<td>5. Content Questions</td>
<td>5 min</td>
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<tr>
<td></td>
<td>6. Professional Speaker via Google Hangout or career videos ?? (see below)</td>
<td>10 min</td>
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<tr>
<td></td>
<td>7. Handout Newsletter upon leaving</td>
<td></td>
</tr>
</tbody>
</table>

What should students know before they leave the club?

- What is the Raspberry Pi?
- What are the parts of a Raspberry Pi?
- How do I setup a Raspberry Pi?
- How to troubleshoot assembly problems with Raspberry Pi?
- What can students do with a Raspberry Pi?

**NC Essential Standards Met**

6.TT.1: Use technology and other resources for the purpose of accessing, organizing, and sharing information
6.RP.1: Apply a research process for collaborative or individual research
7.RP.1: Apply a research process to complete given tasks
8.RP.1: Apply a research process to complete project-based activities

**Next Generation Science Standards**

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet criteria and constraints of the problem.
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
More multimedia sites for further information will be on the North Carolina Science House and Young Engineers Of Today websites!

**General Information**

The Raspberry Pi device was developed by Cambridge professors in Great Britain. According to the Raspberry Pi Website "When we started Raspberry Pi, we had a simple goal: to increase the number of people applying to study Computer Science at Cambridge. By putting cheap, programmable computers in the hands of the right young people, we hoped that we might revive some of the sense of excitement about computing that we had back in the 1980s with our Sinclair Spectrums, BBC Micros and Commodore 64s. (Please see the Raspberry Pi website for further information and video tutorials: [https://www.raspberrypi.org/](https://www.raspberrypi.org/))

**Careers and Additional Multimedia**

- Computer Engineer: [http://www.learnhowtobecome.org/computer-engineer/](http://www.learnhowtobecome.org/computer-engineer/)
  - 12 year old App developer TED Talk- [https://youtu.be/Fkd9TWULFm0](https://youtu.be/Fkd9TWULFm0)
  - Well animated/edited video regarding various related computer careers: [https://youtu.be/1Z1_H7eiPss](https://youtu.be/1Z1_H7eiPss)
- Famous people in computers video: [https://youtu.be/pvAsqPbz9Ro](https://youtu.be/pvAsqPbz9Ro)