STEM PROFESSIONAL VOLUNTEERS IN K-12 COMPETITION PROGRAMS: EDUCATOR PRACTICES AND IMPACT ON PEDAGOGY

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This mixed methods dissertation study explored how secondary school educators in specific K-12 competition programs recruited and deployed STEM professional volunteers. The study explored which practices were viewed as most important, and how practices related to constructivist pedagogy, all from the viewpoint of educators. The non-positivist approach sought new knowledge without pursuing generalized results. Review of the literature uncovered extensive anecdotal information about current practices, and suggested that large investments are made in engaging volunteers. One National Science Foundation-sponsored study was identified, and its recommendations for a sustained research agenda were advanced. Three study phases were performed, one to explore practices and operationalize definitions, a second to rate practice's importance and their relation to pedagogy, and a third to seek explanations. Educators preferred recruiting local, meaning recruiting parents and former students, versus from industry or other employers. Most educators preferred volunteers with mentoring skills, and placing them in direct contact with students, versus deploying volunteers to help with behind-the-scenes tasks supporting the educator. Relationships were identified between the highest-rated practices and constructivism in programs. In STEM professional volunteers, educators see affordances, in the same way a classroom tool opens affordances. A model is proposed which shows educators considering practicality, pedagogy, knowledge and skills, and rapport when accessing the affordances opened by STEM professional volunteers. Benefits are maximized when programs align with strong industry clusters in the community.

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CHAPTER 1

INTRODUCTION

This dissertation study explored how secondary school educators engaged STEM professionals as volunteers in specific K-12 competition programs. The study explored how volunteers were recruited, how they were deployed, and which recruiting and deployment practices educators considered most important. The study also explored how practices related to constructivist pedagogy in the programs under study. The study was conducted within the philosophy of non-positivism, signaling a desire to create new knowledge without pursuing generalized results. Overall, the study pursued improved understanding of educators' core motivations for engaging STEM professional volunteers.

In this introduction, a rationale for the study is provided. The rationale is organized into these topics: the rise of STEM education in the U.S., the role of inquiry-driven pedagogy in STEM education, the importance of outside-the-school adult connections to inquiry pedagogy, the significant resources expended on engaging volunteers, prior anecdotal examples and focused research on STEM professional volunteers, how the current study builds on existing research, and the rationale for assuming the educator's perspective in the current study.

This chapter closes with an overview of the study. Included are an overview of the research questions, research paradigm, participants, methods, assumptions and limitations. A discussion is offered of how successful study completion will create knowledge and lead to broader impacts for society.

1.1 Rationale for Study

1.1.1 The Rise of STEM Education

The most recent fifteen years of K-12 schooling in the United States has been marked by the rise of science, technology, engineering and math, aka STEM, education. In 2001, Judith Ramaley, Director of the National Science Foundation's Education and Human Resources Division, observed that STEM would make a better acronym than SMET, in referring to the relationship between science, technology, engineering and mathematics (Christenson, 2011). Those engaged in STEM have watched the acronym's profile grow, along with the substance of STEM education. At one time, the acronym had to be defined for audiences at education conferences. Today, the acronym is widely used, to the point that it appears in the titles of reports prepared for the U.S. President and effectively needs no definition (Holdren, Lander, & Vamus, 2010). Ramaley observed that, beyond the more pleasing sound of STEM, the acronym visually demonstrates how science and mathematics are the "bookends" (Christenson, 2011, para. 6) that surround technology and engineering in schools. Rather than start an acronym with science and math because they are somehow most important, or most time-honored, the STEM acronym highlights the inter-relationship among the four areas of study (Katehi, Pearson, & Feder, 2009; Bybee, 2010). The acronym highlights that STEM education is not about learning in these four disciplines individually, but about learning them as an integrated whole.

The rise of STEM education can be seen in part through the rise of dedicated STEM schools. In 1998, the U.S. President's Council of Advisors on Science and Technology, or PCAST Panel, reported on the need for reform in the U.S. education system. Scott (2012) interpreted their report as a call for 200 "highly-STEM-focused" (p. 30) high schools and 800 STEM-focused elementary and middle schools within ten years. At the U.S. state level, an example of the response can be seen in Texas, where by 2014, 91 STEM academies had been created with the goal of increasing the number of students engaged in STEM education and ultimately entering STEM careers (Texas Education Agency, 2014).

Additional context comes from consideration of U.S. student achievement, and consideration of the U.S. STEM economy. The most recent Programme for International Student Assessment (PISA) results from 2012 ranked U.S. student performance as average in reading and science, and below average in mathematics, with special concern around mathematics performance requiring higher cognitive processing and the ability to translate real-world situations into mathematical terms (OECD, n.d.). Meanwhile, although the STEM workforce is complex and resists a single interpretation, STEM shortages exist among government employers hiring systems engineering and cyber security professionals, and there is high demand in the private sector for software developers, data scientists, and generally for STEM workers in skilled trades (U.S. Bureau of Labor Statistics, 2015). There is consensus that maintenance of a highly qualified STEM workforce is a long-term and strategic concern for the United States (U.S. Bureau of Labor Statistics, 2015; National Science Board, 2015; U.S. President's Council of Advisors on Science and Technology, 2010).

1.1.2 Inquiry Pedagogy

STEM education, with its interdisciplinary nature, is often delivered with inquiry-driven pedagogy. Prince and Felder (2006) defined inquiry pedagogy as teaching based on students solving real-world or simulated problems, or teaching based on students completing projects, or teaching based on students conducting an inquiry into an issue relevant to the class or student. Nationally, organizations like Project Lead the Way (2014) and the Buck Institute for Education (BIE) (Buck Institute for Education, 2014; Markham, Larmer, & Ravitz, 2003) are providing products and services that support dedicated STEM schools as well as STEM-focused education in traditional schools. The National Research Council (2015, 2011) has repeatedly highlighted the importance of inquiry pedagogy for robust STEM teaching and learning.

1.1.3 Growing Importance of STEM Professional Volunteers

Significant academic literature supports the idea of engaging professionals as volunteers in STEM education. Watters and Diezmann (2013), writing about school partnerships with industry experts, stated that "there is a growing recognition that education needs to engage in partnerships with the community and industry" (p. 47). Veenstra (2014), referencing Raytheon, Ford Motor Company and NASA programs, commented on employers' increasing involvement in supporting secondary education, outreach, and mentoring activities, motivated by their difficulty filling STEM-related jobs. Young (2007) saw in the literature "strong evidence that the properly prepared guest engineering speaker makes a significant impact on recruiting future engineers" (p. 3). Gamse, Martinez, Bozzi and Didriksen (2014), in a rare study focused wholly on professional volunteers, wrote that "providing students with a broader range of exposure…that is more relevant…from a more diverse set of adults…provides greater opportunities to larger numbers of students" (p. 2) to learn about STEM education, careers, and pathways forward.

The previously mentioned example of the Buck Institute for Education (BIE) is especially instructive. Curriculum developed per BIE methods is judged best when it exhibits six attributes: authenticity, academic rigor, applied learning, active exploration, adult connections, and assessment practices (Markham et al., 2003). Attributes like authenticity and exploration are not common in traditional instruction (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Ertmer, 2005). For creating authenticity, one approach BIE advocates is creating connections to adults outside school (Markham et al., 2003). Steinberg (1997, cited in Lattimer & Riordan, 2011) defined adult connections by asking the question, "How do the projects connect students with adult mentors and coaches from the wider community?" (p. 21).

Steinburg (1997), Lattimer and Riordan (2011), and Markham et al. (2003) included adult connections in their criteria for reformed instruction. They described such connections as being valuable to students. Meanwhile, extracurricular programs like FIRST robotics (FIRST, 2016g), Vex Robotics (Vex Robotics, 2015) and CyberPatriot (CyberPatriot, 2015) make significant use of adults from outside schools as mentors for students. These and related efforts sometimes find their way into formal instruction (US FIRST, 2010; TexasAIM.com, 2015), joining formal classroom programs like Project Lead the Way (Van Overschelde, 2013) in bringing adults from outside the school into the STEM education experience of students. Schwartz & Lederman (2002) wrote that adults from the workforce, and especially those from industry, intuitively understand that STEM is interdisciplinary in real-world application. They understand that communication, collaboration, critical thinking, and creativity skills are essential when working in a team to solve problems and make STEM-based products and services.

Another indicator of the increasing importance of STEM professional volunteers comes from the National Science Foundation (NSF). NSF operates a program called Interactive

Technology Experiences for Students and Teachers (ITEST). In this program, NSF specifically requests "projects that examine the effectiveness of engaging adult volunteers with relevant disciplinary expertise from academia or industry to mentor and engage students in school, after school or out-of-school settings" (National Science Foundation, 2015, Program Description, para. 2). This interest tends to confirm that STEM professional volunteers are a growing presence in schools, with sufficient impact on learning and sufficient demand on resources to gain the interest of NSF as a topic for further study.

1.1.4 Resources Expended on STEM Professional Volunteers

The literature indicates that substantial resources are being expended to support STEM professional volunteers in STEM education. Gamse et al. (2014) called the use of STEM professionals "prevalent" and "widely implemented" (p. 17). Among the large companies organizing substantial programs that have placed STEM professionals in secondary education programs are Raytheon, Ford Motor Company, Bayer Corporation, General Motors, and 3M (Davis & Veenstra, 2014; Bayer Corporation, 2010); Lockheed Martin (Lockheed Martin, 2016; National Geographic Society, 2014); and Intel Corporation, Time Warner Cable, Xerox, Eastman Kodak, and ExxonMobil (Change the Equation, 2016). Change the Equation organized 100 corporate CEOs to coordinate a STEM initiative. Large programs engaging STEM professionals have included FIRST (FIRST, 2016a; Melchior, Cohen, Cutter, & Leavitt, 2005), 4-H (Anglin, 2014) and CyberPatriot (CyberPatriot, 2016b). National initiatives have included the U.S. federal government's STEM AmeriCorps, and Citizen School's US2020 national mentorship program. Bogue, Cady and Shanahan (2012) reported an investment of $400 million in outreach by engineering-specific professional societies. They reported, pessimistically, “a dismal return when one considers the primary outcomes metric: how many students choose to enter, and then persist in, engineering” (p. 12).

1.1.5 Mostly Anecdotal Examples; Some Focused Research

Most often observed in the literature are anecdotal examples of STEM professional volunteer engagement. One can read about cases, understand that adult volunteers were used, and get a sense for their role and purpose. A particularly illustrative example is Edelson, Gordin and Pea’s (1999) case study of the CoVis geographic visualization environment. The study’s thick, qualitative description made clear that GIS professionals were involved in the students’ education, and the study suggested how the professionals were engaged. However, the study was focused on qualitative description of the effort as a whole, and did not offer rigorous examination of the role and effectiveness of STEM professional volunteers.

Other case studies also described the involvement of adult volunteers around specific topics. Cuban (1986) wrote on the history of computers in classrooms, making clear that professional volunteers have been engaged over the long history of U.S. K-12 education. The American Association of Engineering Societies (1997) described multiple K-12 engineering education programs deploying volunteers. Brophy, Klein, Portsmore and Rogers (2008), Katehi, Pearson and Feder (2009), and Rogers and Portsmore (2004) noted professional volunteer involvement in engineering education. Barr and Stephenson (2011) described professional volunteer engagement in computational thinking in schools. Hobbs and Jensen (2009) wrote about industry involvement in media literacy education, including the recent impact of technology. In other literature, the direct involvement of STEM professional volunteers was not explicitly stated, but industry involvement in secondary education efforts was described. For example, Grover and Pea (2013) described the role of industry on K-12 advisory boards for computational thinking curriculum. Hailey, Erekson, Becker and Thomas (2005) wrote about industry involvement in student internships in engineering and technology education. Though a careful reading of those references does not explicitly describe volunteers at work in schools, one can see volunteer engagement as a natural part of the work described.

1.1.6 Current Research, Gaps, and Proposed Research Topic

Looking deeper, a review of recent ITEST awards is useful for illustrating both the state of knowledge in this area, and the potential for creating new knowledge through the proposed study. Using the keywords *adult*, *volunteer*, *industry*, *professional*, and *mentor*, a review of 98 recent ITEST awards identified twenty-one projects that included STEM professional volunteers. However, despite the ITEST language that emphasized a desire to understand the impact of STEM professional volunteers, only one study abstract indicated a specific goal of understanding the effectiveness of STEM professional volunteers (Stevens & Andrade, 2012). In a search for additional program reports and literature on that project, no specific results related to STEM professional volunteers were discovered.

In the literature, there is keen awareness among authors of the lack of evidence supporting the benefits of STEM professional volunteers. Young (2007) wrote that engineering guest speakers are overlooked in the literature. Laursen, Liston, Thiry and Graf (2007), referring to short duration visits of scientists to classrooms, called belief in positive effects “largely a matter of faith: little research literature documents their effectiveness" (p. 50). Discussing professional engineering society programs, Bogue et al. (2013) wrote that outreach to children and young adults is a satisfying goal for society members, but it is not known "whether these activities achieve the overarching goal of encouraging people to enter and persist in engineering studies and, ultimately, to pursue careers in the science, technology, engineering, and mathematics (STEM) fields" (p. 11). These are not new questions. Weinberger (1992) wrote that business and industry leaders were questioning whether "'feeling good' about partnership activities is adequate for addressing the critical issues facing our nation's schools" (p. 7). Speaking specifically to the impact of STEM professionals, Gamse et al. (2014) reported the difficulty of determining, for a program with many elements, whether outcomes can be attributed to the involvement of STEM professionals.

In fact, the most direct study of STEM professional volunteers is found in Gamse et al. (2014). In *Defining a Research Agenda for STEM Corps: Working White Paper*, the authors described an original goal of synthesizing research on outcomes from the direct engagement of professionals with secondary STEM students. The authors concluded that little prior rigorous research existed, and within that limited body of rigorous research, it was not possible to separate the effects of STEM volunteers from other program elements. Therefore, the authors opted to recommend a research agenda. Their proposed agenda consisted of four steps: (1) articulating practices involving STEM-trained professionals; (2) developing theories of action or logic models theorizing connections between practices and student outcomes; (3) investigating theories and models through exploratory empirical research; and (4) developing additional tiered evidence of increasing rigor.

Building on the anecdotal reports from the literature, on the apparent enthusiasm and resource expenditure on STEM professional volunteers, and on the clear questions about volunteer effectiveness—and especially building on the Gamse et al. (2014) recommended research agenda—the current study will explore the practices educators use to recruit and deploy STEM professional volunteers. In particular, this study will directly address Gamse et al.'s Research Agenda Item 1, articulation of practices involving STEM-trained professionals. The broad base of anecdotal reports on the use of STEM professional volunteers provides a foundation from which a nascent list of practices can be developed, explored and refined through the current study. In addition, the current study will make contributions to Gamse et al.s' Research Agenda Items 2 and 3, developing theories of action and testing them through exploratory empirical research. Progress will be made by exploring relationships between educators' practices and the presence of constructivist, inquiry pedagogy.

1.1.7 Assuming the Perspective of Secondary Educators

Cuban (1986, 2001) argued strongly that secondary educators (teachers and administrators) are key to the success of reform efforts in secondary schools. Cuban's review of one-hundred years of secondary reform efforts demonstrated repeatedly the central role educators must play. More recently, Ertmer et al. (2012) wrote about both the barriers educators represent if they are not consulted in reform efforts, and also their ability to succeed in the face of barriers when they are advocates for reform. Harris (2005), Hall and Hord (1987), and Anderson (1997) also highlighted the importance of incorporating teacher perspectives into education reform efforts. In light of this evidence, I made the intentional choice to consider questions about STEM professional volunteers from the perspective of secondary educators. The current study will focus on educators' practices for recruiting STEM professional volunteers, how educators deploy those volunteers, the relationship to their pedagogical practices, and the deeper reasons educators value STEM professional volunteers.

1.2 Purpose of Study and Research Questions

One main research question and four sub-questions were identified. The main research question was: How do secondary educators relate to STEM professional volunteers? The sub-questions were:

- Which practices used to recruit STEM professional volunteers are most important to educators?
- Which deployments of STEM professional volunteers are most important to educators?
- What relationships exist between: (1) educators' practices for recruiting and deploying STEM professional volunteers, and (2) the constructivist pedagogical practices present in the programs under study?
- Why do STEM educators pursue relationships with STEM professional volunteers?

1.3 Participants

The participants for this study were educators who serve as coaches in the CyberPatriot competition in San Antonio, Texas. CyberPatriot is a national cyber defense competition sponsored by the Air Force Association (CyberPatriot, 2015). In the competition, student teams compete against other teams in the field of protection of computing devices, referred to in the competition as *cyber defense*. The program features local, regional and national competitions.

The naming of the San Antonio CyberPatriot Center of Excellence, so recognized in February of 2012, highlighted the capabilities of the San Antonio community in operating a regional CyberPatriot program (CyberPatriot, 2016b). The 2011-2012 Open Division champion was a team from the Information Technology and Security Academy (ITSA) in San Antonio. In 2015-2016, 192 teams from the region competed. An essential part of the program is the recruiting and training of students, educators and adult volunteers. While I am not an active participant in the CyberPatriot competition, I helped develop the curriculum for the region's emerging middle school program, and was a co-founder of ITSA in 2002. My relationships to the program leaders facilitated access to program educators. It is also a bias that is disclosed and must be managed in the current study.

To expand the participant sample available for the study, selected educator participants were also included who are coaches for robotics teams in FIRST-Alamo Region. FIRST (For Inspiration and Recognition of Science and Technology) (FIRST, 2016g) is a well-known national robotics competition with goals related to promoting STEM education and careers. The FIRST competition exhibits many common attributes with CyberPatriot as it relates to the current study: a focus on secondary STEM education, primarily extracurricular, inquiry pedagogy, educators as coaches, wide use of STEM professional volunteers, training programs for coaches, volunteers and students, and a local and national competition structure. The inclusion of FIRST-Alamo Region participants helped reduce the risk of study mortality. This benefit was judged more important than the study fidelity risks introduced, which were judged to be minimal in light of FIRST's common attributes with CyberPatriot.

1.4 Research Paradigm

The critical theory research paradigm (Guba & Lincoln, 1994) was adopted for this study. Guba and Lincoln argued that positivism is not the only way of knowing the world. There are alternative paradigms in which observations are allowed to emerge from activities that are not contrived for the purposes of research, but rather happen as normal life events. While such settings are inherently more complex, they also provide a more realistic setting for social science research, and research results are more likely to reflect field conditions. Also called naturalistic inquiry (Lincoln & Guba, 1985), the paradigm embraces the idea that causal hypotheses are not required for rigorous research, but that rigorous methods can be deployed to observe, define and document knowledge that emerges from the inquiry process.

The critical theory paradigm, while not positivist, remains within the domain of ontological realism. Critical theory acknowledges an objective reality, but also allows that such reality is affected by social, political, cultural and other considerations, and that reality exists within local context. Critical theory allows a place for values and advocacy, which exists in the current study for me and the study's participants. Critical theory is consistent with an objective reality, whose first characterization in this study emerged from review of the general literature on STEM professional volunteers.

Critical theory is non-positivist. In the current study, the term *non-positivist* is used to refer to ontologies and epistemologies not fully committed to the traditional view of an external, independent and objective reality (Stahl, 2007; Alexander, 2006; Mingers, 2004; Fournier, 2000; Falconer & Mackay, 1999; Ashworth, 1997). My adoption of critical theory and its non-positivist framework signaled the lack of intent to generalize results beyond the participants under study (Lincoln & Guba, 1985; Guba & Lincoln, 1994; Creswell & Plano Clark, 2011). This study attempted to better describe and define the behavior of educator-participants as they recruited and deployed adult volunteers. No attempt is made when reporting the study to argue for generalized causal or correlative relationships. Nevertheless, it is true that I intend to add knowledge to the field that others will find useful. It will be left to the reader to determine if the results of the study apply to situations for which they have personal and/or expert knowledge.

1.5 Methods

In support of the critical theory paradigm, mixed methods (Creswell & Plano Clark, 2011) was adopted for execution of the study. Creswell and Plano Clark argued that a mixed methods approach leverages the strengths of qualitative and quantitative research, with the strengths of each offsetting the weaknesses of the other. Creswell and Plano Clark described different configurations of mixed methods studies observed in use in the field. In exploratory mixed methods, an initial qualitative phase is used to better document a phenomenon and make it known to the researcher. A second quantitative phase then is executed, building on the knowledge gained in the initial qualitative exploration. In explanatory mixed methods, a follow-up qualitative phase is executed following a quantitative study. Such an effort more fully characterizes a story that can only be partially explained through numbers.

The current study implemented an exploratory and explanatory mixed methods design. As described above, the literature is rich with cases of STEM professional volunteer engagement, but these cases are spread across numerous studies. In the exploratory phase, qualitative methods were used to centralize, sharpen, and better operationalize the definitions of educator practices related to STEM professional volunteer engagement derived from the literature. A second phase brought the strengths of quantitative research and a validated instrument to bear to analyze the research questions. An explanatory qualitative phase built on first and second phase results, completing the characterization of how educators engage with STEM professional volunteers, how pedagogy is related, and why educators engage STEM professional volunteers. I argue that the risk of poor definition of educator practices, and the risk of a substantially incomplete understanding of why certain educator practices are undertaken, warranted the mixed methods approach.

I highlight for the reader the importance of the literature review to the overall study design. The study was grounded in educator practices for STEM professional volunteer engagement. The first characterization of these practices was derived from the literature. This study's contribution to the field includes the aggregation of this list, along with improved operational definitions of the derived practices. This study's literature chapter concludes with a first version of the aggregated practices list as derived from the literature.

1.6 Value of Study Outcomes

Beyond the development of new knowledge, potential exists for practical, broader benefits resulting from the study. Literature review results indicated that educators and others who care about STEM professional volunteers in schools are operating based on anecdotal experience, hearsay about what works, and formal program training on volunteer engagement that may or may not have been grounded in rigorous practices (Gamse et al., 2014; Bogue et al., 2013; Laursen et al., 2007; Young, 2007; Weinberger, 1992). On the one hand, I wish to be cautious about stating that such sources are ineffective at informing adult volunteer-related activities. In fact, the qualitative phases of this study, in many ways, leaned on the same mechanisms of individual, anecdotal perspectives.

However, it is also the case that formal research is performed to confirm or contradict such beliefs. The current study was performed to confirm and/or contradict elements of how educators engage with STEM professional volunteers. To the extent that the study results are found credible by programs that engage volunteers, and by individual educators who engage volunteers, the study can lead to emphasis of selected practices and de-emphasis of others, and to overall improvement of how STEM professional volunteers are engaged. To the extent such volunteers impact student motivation, student engagement, and/or teaching methods that lead to improved core content knowledge or 21st century skills, this study may contribute to generation of more such outcomes. Even if the study largely confirms current practice, academic dissemination of results may lead to more widespread understanding of how to engage STEM professional volunteers, and also to more consistent application among practicing educators.

1.7 Assumptions and Limitations

The absence of a positivist framework and the mixed methods approach of this study limit generalizability. Study results apply only to the participants studied, and it is left to the reader to determine applicability to other settings. Because participants were associated with the San Antonio-area CyberPatriot and FIRST programs, circumstances unique to this setting may restrict applicability to other settings. In particular, it is noted that the San Antonio-area CyberPatriot and FIRST teams follow formal locally-developed training programs that complement the national training programs. As previously noted, I had been involved in small ways in the current program, and was involved as a principal in the formation of one Academy that is a core program participant. This bias must be managed and should be considered by readers when interpreting results. Finally, it is noted that the study is being conducted based on the perceptions of secondary educators. Their biases must be considered when interpreting outcomes.

CHAPTER 2

REVIEW OF RELATED LITERATURE AND THEORY

This literature review establishes the philosophical, theoretical, contextual and practical foundation for the current study of STEM professional volunteers in K-12 competition programs. After establishing definitions, the core philosophies of STEM education reflected in this study will be explored. The education theories and other related theories that inform study design will be reviewed.

Then, the practical foundation for the current study will be set. This foundation includes relevant history regarding inquiry learning and education reform, a review of themes from anecdotal cases of STEM professional volunteers, and a review of large-scale programs organized by industry and non-profits to support STEM education. A review of the few studies focused on professionals engaged in STEM education is provided.

Core to the practical foundation of the study is a rigorously-formed list of practices educators have employed to recruit and deploy STEM professional volunteers, based on the literature. These practices form the launch point for Phase 1 data collection. It is noted in advance for the reader that the literature provides a more robust set of volunteer deployment practices than recruiting practices. Nevertheless, starting points for both are established to support the remainder of the study.

Next, literature background is provided for the study's methods and rigor. Finally, a full description is provided of the programs under study. Described are the CyberPatriot program and its implementation in the San Antonio region, and the FIRST-Alamo Region program and its local implementation.

2.1 Definitions

2.1.1 Defining STEM Education

This study's introduction described the history of the term *STEM* and how it came into common use in the United States. Ramaley's introduction of the term (Christenson, 2011) referred to the science and mathematics "bookends" (para. 6) that surround technology and engineering. The inter-relationship among the four areas is emphasized (Katehi, Pearson, & Feder, 2009; Bybee, 2010). At its roots, STEM education is not about one subject individually, but about interdisciplinary teaching and learning.

Beyond such useful but general statements, the consensus of the literature is that STEM is difficult to fully define, "the most elaborate puzzle in the education world" (Gerlach, 2012, para. 1). There is broad agreement that, as a practical matter, definitions are most useful when defined for local context (Gerlach, 2012; Bruce-Davis, Gubbins, Gilson, Villanueva, Foreman, & Rubenstein, 2014; Breiner, Harkness, Johnson, & Koehler, 2012; Chiu, Price, & Ovrahim, 2015; Bybee, 2010). Breiner et al. recommended focusing on outcomes. The desired outcome described by Breiner et al. is "creating better teachers, students, and workforce in order for the United States to better compete globally" (p. 277).

Meanwhile, Gerlach (2012) shared and critiqued a definition from Tsupros, Kohler and Hallinen (2009). Many elements of the definition find support in other literature: applying science, technology, engineering and math in context; interdisciplinary approaches; coupling academic concepts with real-world lessons; making connections between community, work, school and global challenges; and preparation for the workforce (Gerlach, 2012; Bruce-Davis et al., 2014; Breiner et al., 2012; Chiu et al., 2015; Bybee, 2010; Markham et al., 2003). Other researchers have included in their STEM descriptions: the 4 Cs—communication, collaboration, critical thinking, and creativity (DeJarnette, 2012); authenticity in activities and academic content (Breiner et al., 2012; Markham et al., 2003); inquiry learning approaches (Breiner et al., 2012; Markham et al., 2003); and inclusion of humanities-related subject matter outside the four traditional disciplines (Chiu et al., 2015; Bybee, 2010; Sanders, 2009).

Adapted from Tsupros et al. (2009), while also drawing on elements of other definitions, the following definition is adopted for the current study:

> STEM features: (1) a focus on science, technology, engineering and math; (2) mixed at times with other subjects; (3) using an interdisciplinary, inquiry approach; (4) incorporating authentic real-world lessons; (6) integrating important academic content; (7) advancing the 4 C's; and (8) advancing student opportunities for college and careers.

2.1.2 Other Definitions

Professional is defined as a person "engaged in one of the learned professions" (Merriam-Webster, 2016a), where a profession is "a type of job that requires special education, training, or skill" (Merriam-Webster, 2016b). A professional can come from any sector of society: industry, government, non-profit, higher education, or secondary education, but strictly for convenience and brevity in this study, a professional specifically refers to a person from industry, government or non-profits, or stated differently, from outside education.

Volunteer is defined as "a person who does work without getting paid to do it" (Merriam-Webster, 2016c). In addition, volunteer is also used as a shorthand for STEM professional volunteer, as defined below, with its use in this manner determined from context.

STEM professional volunteer is defined as a volunteer professional whose primary work is performed in careers consistent with the definition of STEM education provided above.

Teacher is defined as "a person whose job is to teach students about certain subjects" (Merriam-Webster, 2016d). For this study, teachers refer to those teaching in Grades K through 12 unless otherwise stated.

Secondary teacher is defined as a teacher in the secondary grades, post elementary school, typically Grades 6 through 12.

Secondary educator is defined as "a person (such as a teacher or a school administrator) who has a job in the field of [secondary] education" (Merriam-Webster, 2016e). For this study, the term educator is frequently used to make it clear that the people being referred to are not just active classroom teachers, but all those employed in secondary education, recognizing that many if not most administrators are former classroom teachers.

Employer is defined as "a person or business that employs one or more people, especially for wages or salary" (Dictionary.com, 2016a). For this study, the term employer is used to make clear that volunteers can come from industry, government or non-profits.

Industry is defined as "trade or manufacture in general" (Dictionary.com, 2016b), and in this study, it refers to for-profit employers.

Practices is defined as "(something) [you do] regularly or constantly as an ordinary part of your life" (Merriam-Webster, 2016f), and for this study, it refers specifically to practices of educators related to the topic of the study.

Instrument is defined as a written research tool, quantitative or qualitative, printed or online, for which peer-reviewed publications exist that show the instrument to be valid and reliable in specific prior uses.

Survey is defined as a written research tool, quantitative or qualitative, printed or online. For this study, survey is used to refer to newly developed tools for measurement which lack evidence of validation (in other words, tools that do not qualify as instruments).

2.2 Philosophical and Theoretical Foundations

2.2.1 Research Philosophy

Guba and Lincoln (1994) described four research "paradigms" (p. 109) for the social sciences: positivism; post-positivism; critical theory et al.; and constructivism, previously called naturalism in Lincoln and Guba (1985). The critical theory et al. paradigm referred collectively to multiple paradigms where the values of researchers and participants inform inquiry, while remaining in the domain of ontological realism. The four paradigms run generally on a continuum from (1) viewing the world as defined by a clear and measurable objective reality, to (2) viewing reality as fully observer dependent, context dependent, value-system-informed, with knowledge emerging only through discourse from local settings. Guba and Lincoln contrasted the four paradigms along the metaphysical categories of ontology, epistemology and methodology, and they contrasted the four paradigms along several "practical issues" (p. 112) which included inquiry aim, goodness or quality criteria, values, ethics and hegemony.

The current study is within the paradigm (philosophy) of critical theory et al., from here forward simply called critical theory. Habermas (1978) identified critical theory as balancing three interests, which colloquially stated are control, the welfare of others, and awareness/critique of context (Taylor, Fraser, & White, 1994). Guba and Lincoln (1994) described the critical theory paradigm as being: (1) ontologically real, but formed over time by "social, political, cultural, economic, ethnic, and gender factors, and then crystallized (reified)"

(p. 110); (2) epistemologically subjective, where the investigator interacts with subjects, and values of the investigator and subjects influence the investigation; and (3) methodologically approached with dialog between investigator and subjects, seeking to “transform ignorance and misapprehensions (accepting historically mediated structures as immutable) into more informed consciousness (seeing how the structures might be changed and comprehending the actions required to effect change)” (p. 110). Guba and Lincoln’s (1994) practical issues for critical theory incorporated critique and transformation of structures, advocacy and activism, investigator as instigator and facilitator, structural/historical insights transformed over time to more informed insights, investigation situated in place and in values, consideration of at-risk audiences, and a place for emergent inquiry. Figure 2.1 illustrates the fit of critical theory along a continuum defined by positivist versus non-positivist viewpoints, also contrasting the other three Guba and Lincoln research paradigms.

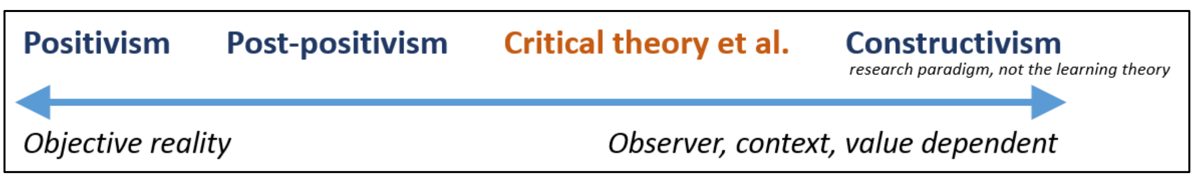


Figure 2.1. Critical theory et al. on the positivist vs. non-positivist continuum.

The term *non-positivist* is used to refer to research philosophies or paradigms that, in part or in full, do not subscribe to positivist approaches (Stahl, 2007; Mingers, 2004; Fournier, 2000; Falconer & Mackay, 1999; Ashworth, 1997). Some authors have portrayed positivism and non-positivism as unable to co-exist at any level, while others have maintained that coordinated use of associated research methods, well designed, can improve research outcomes within an overall non-positivist design. I adopt use of the term *non-positivist* to indicate any research approach that is not fully committed to viewing reality as external, independent and objective. Use of the term signals intent not to generalize results beyond the current study, since reality elsewhere emerges from local settings. Use of the term does not rule out use of quantitative methods usually associated with positivist research. Resulting knowledge can still be used to build understanding of the local setting under study (Creswell & Plano Clark, 2011).

I call the reader's attention to the appropriateness of the attributes of critical theory to the study at hand. I and the study's subjects are all advocates for STEM education and its transformational power, including its power to transform the lives of students and families from underrepresented populations. I will investigate which STEM professional volunteer recruiting and deployment practices are most important to educators, and how constructivist teaching and learning is affected by the engagement of STEM professional volunteers. Historical practices derived from the literature will be critically reviewed in local context, with the possibility of context-aware dissemination to other settings.

Two important literature highlights are shared to clarify, enrich and conclude discussion. First, the difference is noted between *constructivist research philosophy*, as described by Guba and Lincoln (1994), versus *constructivist learning theory*. Constructivist research philosophy concerns how research is structured to investigate people's behavior, creating new knowledge from the research. Constructivist learning theory is about how individual people or groups of people learn (Ertmer & Newby, 1993; Prince & Felder, 2006), which in the current study is the *target* of research. I embrace constructivist learning theory for the current study, as further described below. I also note that constructivist research philosophy accents the research design. Context is local, and ample opportunity is provided for subject voice to emerge. Once historical structure is established from literature, the focus is on the emergence of subject voice. Nevertheless, by grounding this study in practices retrieved from literature, and in critiquing these practices as an important study outcome, the study's research philosophy is largely centered on critical theory, with constructivist research philosophy serving as a commensurable addition (Guba and Lincoln, 1994).

2.2.2 Philosophy of Being and Knowing

Philosophers have long discussed what is real in the world, how we can know what is real, and how we can know the nature of knowledge. The philosophies that have emerged are in turn the basis for educational theories embraced in this study. Understanding these philosophies creates a rich context for study design and interpretation of results.

Ertmer and Newby (1993) started their description of modern learning theories with a return to seminal ideas from Aristotle and Plato. Aristotle believed that experience is the primary source of knowledge (Schunk, 1991). Multiple sensory impressions combine to form complex ideas. Plato took the alternate view that knowledge is the result of reason. He believed that knowledge can be constructed in the minds of people without any assistance from the senses (Schunk, 1991). Aristotle's view that knowledge comes from the senses and experience is called *empiricism*. Plato's view that the mind can create knowledge is called *rationalism*.

Ertmer and Newby (1993) brought senses and experience together in their description of constructivist learning theory. Moving beyond the previously established theories of behaviorism (an empiricist view) and cognitivism (a rationalist view), constructivism synthesizes empiricism and rationalism. The mind creates its own meaning, but this creation of meaning is strongly influenced through the iterative process of gaining real-world experience. Interpretations of the world are personal, and "knowledge emerges in contexts within which it is relevant" (p. 63).

Prince and Felder (2006) picked up these themes via the 18th century philosophies of Kant and Vico, connecting them to modern inductive, inquiry-based teaching methods. Kant wrote that both our senses and our existing understanding mediates what we know about the world—that the "intelligible...world is strictly unknowable to us" (Stanford Encyclopedia of Philosophy, 2010, Life and Works, paragraph 12). Vico wrote that we can never know an original thing but only its causes, and that humans tend to envelop things with "what is familiar and at hand" (Stanford Encyclopedia of Philosophy, 2012, The New Science, para. 3). Glasersfeld (2007) stated that people create personalized meaning, which in turn becomes those people's reality. Prince and Felder asserted these ideas as embedded not just in constructivism, but in the specific inquiry-, problem-, and project-based learning techniques seen in modern classrooms. Students construct their own knowledge and create their own meaning and reality through inquiry experiences. Authenticity emerges from these learning experiences (Rahm, Miller, Hartley, & Moore, 2003).

2.3 Learning Theory

2.3.1 Constructivism

Among the established learning theories of behaviorism, cognitivism and constructivism (Ertmer & Newby, 1993), constructivism is by far most associated with the kind of interdisciplinary, inquiry-based, real-world-related STEM programs that are the target of the current study (Ertmer et al., 2012; Ertmer, 2005; Hmelo-Silver, Duncan, & Chinn, 2007; Prince & Felder, 2006). Prince and Felder offered the following description of constructivism:

> Constructivism…holds that...individuals actively construct and reconstruct their own reality in an effort to make sense of their experience. (p. 124)

Dewey and Schwab helped establish the foundation of constructivist learning theory. Dewey (1997, 1900) resisted the idea that science is only about facts, and advocated that science is about a way of thinking, and about process. Schwab engaged in long-term, sustained efforts to reform science education, advocating teaching science as a complex process, and as an inquiry-based process (National Research Council, 1996). Schwab asserted that three activities are fundamental, "asking questions, collecting data, and interpreting those data" (Abrams, Southerland, & Evans, 2008).

Among the variations of constructivism are cognitive constructivism and social constructivism (Prince and Felder, 2006). Originating in the works of Piaget, *cognitive constructivism* is the theory that people are active in processing information, and they create meaning from that information, building their own reality. Their cognitive activity accommodates the reality they encounter (Glasersfeld, 2007). *Social constructivism*, with roots in Vygotsky (1978), is the theory that meaning emerges only from social interaction. History and culture are essential in creating this meaning, which emerges from intersubjective discourse among a group of learners.

STEM professional volunteers are brought into programs for purposes consistent with the constructivist theory of learning. They are asked to share stories about their real-world experience (Forssen, Lauriski-Karriker, Harriger, & Moskal, 2011; Recio & Gable, 2007; American

Association of Engineering Societies, 1997) and to add context to academic content (Chiu et al., 2015; Watters & Diezmann, 2013; Gamse et al., 2014; Bachrach, Manning, & Goodman, 2010). They are asked to mentor students in coursework and projects (Bruce-Davis et al., 2014; Bayer Corporation, 2010), to help students learn how to work in groups (Gamse et al., 2014; Karp, Gale, Tan, & Burnham, 2014; Veenstra, 2014; Lattimer & Riordan, 2011) and to mentor students in critical thinking and communication skills (Lattimer & Riordan, 2011; Katehi et al., 2009). Such activities build confidence in students engaged in STEM activities (National Research Council, 2015; Bogue et al., 2012).

2.3.2 Social Learning Theories

Social constructivism is just one of several related perspectives on the role of social interaction in learning. *Situated cognition* is the idea that "activity and situations are integral to cognition and learning" (Brown, Collins, & Duguid, 1989, p. 32). Brown et al. argued that "[in] ignoring the situated nature of cognition, education defeats its own goal of providing useable, robust knowledge" (p. 32). Those authors proposed an approach to teaching and learning called *cognitive apprenticeship*. Cognitive apprenticeship incorporates practice in a variety of situations, reflective comparison to others' work, learning in context, and working with others (Collins, 2006). In social cognitive theory, Bandura (1994) emphasized the role of self-efficacy, the belief in one's own ability to succeed. Social and self-efficacy concerns are seen throughout the literature on STEM teaching and learning (e.g., National Research Council, 2015; Chiu et al., 2015; Bruce-Davis et al., 2014; Lattimer & Riordan, 2011; Bogue et al., 2012; Bayer Corporation, 2010; Katehi et al., 2009; Recio & Gable, 2007; American Association of Engineering Societies, 1997). These social learning theories enrich constructivism's meaning in the current study.

2.3.3 Constructionism

Papert & Harel (1991) described constructionism as a constructivist learning theory advancing the creation of tangible products as a highly effective mechanism for learning. The artifacts created are subject to peer critique. Papert and Harel argued that constructionism contains a richness that is not immediately apparent. Beyond the direct benefits of learning through doing, constructionist pedagogy can lead students to big ideas that are often lost in the effort to apply consistent, measurable pedagogy in schools (Papert, 2000). Papert cited a particular example where a low-performing student saw beyond the violence of a rat trap, and recognized its inventiveness. Papert observed a virtuous cycle, where the meaning learners create for themselves can in turn inspire them to learn.

2.3.4 Embodiment in Instructional Methods

As previously described, Prince and Felder (2006) noted inquiry learning, problem-based learning, and project-based learning as three specific methods compatible with constructivist learning theory and appropriate for delivering "inductive" (p. 123) instruction. Those three instructional methods embody the learning theories described. Prince and Felder wrote that inductive instructional methods always have at least some of the following features, varying in intensity between methods: (1) questions/problems with learning content; (2) problems that are complex, open-ended, and real-world-based; (3) projects significant in size; (4) students discovering course content; (5) instructors adjusting according to student responses; (6)

students self-directing and active; and (7) learning as team-based. Similar attributes are noted by Markham et al. (2003), in Buck Institute for Education materials, within their definition of project-based learning. Their definition incorporates authenticity, academic rigor, applied learning, active exploration, adult connections, and assessment practices. Based on Prince and Felder's initial description of the term, I adopt inquiry learning as an umbrella term that refers to the inquiry-, problem-, and project-based methods seen in STEM instruction.

2.3.5 The Educator's Role in Changing Classroom Practice

To the extent that the use of STEM professional volunteers in secondary education is growing (National Science Foundation, 2015; Gamse et al., 2014), substantial literature strongly suggests that educators, and especially classroom teachers, must be central to growth strategy. Cuban (1986) reviewed almost one-hundred years of secondary education reform efforts, covering times of enthusiasm related to the invention of radio, of film, and of computers and digital media. Much potential was perceived for teaching and learning. With few exceptions, efforts that attempted top-down reform mandates without considering the practical moment-to-moment needs and learning-standards expectations of teachers did not succeed. Jones and Warren (2013) identified some of the factors that inhibit STEM reform in classrooms, including time, technology readiness, and relevance to classroom goals. Ertmer et al. (2012) documented how unaligned teacher beliefs stopped classroom implementation of new pedagogies, but also how an aligned teacher can not only succeed, but do so in the face of significant barriers. The Center for Adult and Experiential Learning (2011) documented a recent case where a lack of coordination with local teachers led to barriers in the engagement of otherwise enthusiastic professional volunteers. Educators' engagement as stakeholders in reform of the teaching and learning process is essential.

As one might therefore expect, models and associated instruments have been developed to help understand and measure teacher adoption in classrooms. The Concerns-Based Adoption Model (CBAM) (Hall & Hord, 1987) was derived from observation of how teachers' concerns evolve during the process of adopting new classroom pedagogies. Teacher concerns are expected, and ultimate success is dependent on the ability to address those concerns. Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006) is a model that addresses teachers' ability to not simply bring technology into classrooms, but to integrate that technology with a compatible pedagogy, and toward the goal of teaching academic content. The existence of these models is further evidence of the importance of educators in general, and classroom teachers in particular, when bringing new ways of teaching into secondary education. This role of educators forms the rationale for conducting this study from the perspective of educators.

2.4 Other Theory

Two theoretical perspectives from outside education informed this study's selection, and in small to moderate ways, its design. The first outside perspective is the *technopolis* model, from the fields of technology and economic development. The model addresses how sectors in a region work together for the purpose of building technology-driven, knowledge-based economies. The second outside perspective is research on volunteerism.

2.4.1 Technopolis Model

The technopolis model (Smilor, Gibson, & Kozmetsky, 1989; Gibson, Kozmetsky, & Smilor, 1992; Gibson & Butler, 2013) is a theory for how technology-driven, knowledge-based economies develop, and how such regional economies gain advantage over competitors. The model is expressed by the technopolis wheel, through which a regional economy advances. The spokes of the wheel are universities, large corporations, emerging companies, federal government, state government, local government, and support groups.

Within the state government spoke is educational support. An example of technopolis educational support in action is seen in a strategic planning project performed to help raise the competitiveness of the Cameron County border region in South Texas. Gibson, Rhi-Perez, Cotrofeld, De Los Reyes and Gipson (2003) reported that "improving the quality and availability of [secondary] education [was identified by] business and community leaders as the single most important task facing the region" (p. 40). One activity of the regional partnership was a career and technology program, supported by local employers, and enabled by a mobile technology lab. Lessons from the technopolis model add to the rationale for the current study. The sectors described in the technopolis model influenced design of this study's survey of volunteer recruiting practices.

2.4.2 Volunteerism

Although the current study focuses on educators' perspectives on how volunteers are recruited and used, it also useful to consider essentials of volunteerism from the perspective of the volunteers. Penner (2002) proposed a model to describe the process by which a person chooses to become a volunteer (for any cause, not specific to STEM or education), and how some volunteers persist over time. Among the factors in the model are personality, personal beliefs and values, practical motivations, social pressure, situational factors (e.g., a driving national need), and factors related to the organization receiving volunteers.

Clary et al. (1998) and Clary and Snyder (1999) studied volunteerism from the perspective of the psychological motivations of the volunteers. Building on functionalist theory, they proposed these main psychological motivations: (1) acting on important values; (2) improving one's understanding of the world by using otherwise unused skills; (3) general personal growth and development; (4) gaining career-related experience and creating the basis for career advancement; (5) advancing social relationships; and (6) protective action against one's negative feelings or personal problems. Smith (1981) concluded that volunteers are neither altruistic nor selfish, but rather choose to volunteer to "achieve ends which the volunteer finds rewarding" (p. 21). A volunteer's reasons for volunteering may or may not match the goals of the educator. Bogue et al. (2012) noted that in any program strongly incorporating volunteers, the program risks become about the volunteers instead of the students.

2.5 Practical Foundation

To establish a practical literature foundation for the study, this section will begin with a review of the history of engagement of professionals in STEM education, including a review of programs over the last two decades organized to bring STEM volunteer professionals into classrooms. Brief discussion will be provided about how volunteers are organized and how individual volunteers are prepared for their task. A summary of the few studies that have focused on STEM professional volunteer effectiveness will be provided.

The core component of this practical literature foundation is the review of educator practices when recruiting and deploying STEM professional volunteers. An extensive literature review was conducted to identify how educators recruit volunteers, and especially how they use those volunteers once engaged. This component of the literature review provided the launch point for Phase 1 of the current study.

2.5.1 Historical Perspective on STEM-Type Learning in Secondary Schools

Bringing outside STEM help into secondary schools is not a new idea. Cuban (1986), writing about the long history of bringing technology (e.g., radio, film) into classrooms, noted the roles played by subject matter professionals. Young (2007) highlighted three studies that explored young students' perceptions of scientists and engineers, one from 1957, one from 1986, and one from 2007, with all three studies consistently showing the need to change often unflattering student perceptions of scientists and engineers.

Industry and community support for schools received a "boost" (p. 7) in 1983 when President Reagan launched the National Partnership in Education program (Weinberger, 1992). More recently, the National Association of Partners in Education estimated the existence of 200,000 partnerships in the United States. The American Association of Engineering Societies (1997) summarized fourteen programs featuring engineers supporting educators. Sussman (1993) edited a book on science education partnerships. Among the book's 33 chapters are multiple common themes: running partnership programs; perspectives of educators; comments on individual volunteers; comments on small, medium and large volunteer programs; and descriptions of industry-driven medium and large volunteer programs. Instructional/program models and/or foci included preservice education, student service learning, curriculum co-development, underrepresented populations, fundraising, and systemic change. Examining this history makes clear both the long-term nature of professionals helping secondary educators, and the variety of ways, timescales, and approaches present in such programs.

2.5.2 STEM Volunteer Training and Models

There are a wide variety of models connecting STEM professional volunteers to schools, and different ways volunteers can be prepared for their task (Gamse et al. 2014; Bogue et al., 2012; Liston, Peterson, & Ragan, 2008; Laursen et al., 2007). Resources exist along a spectrum supporting programs from very small to very large scale. One can find individual accounts of volunteers sharing their experience and advice, and one can find highly formalized programs that train volunteers en masse before they begin service. Gamse et al. (2014) noted different approaches and distinct roles filled by STEM professionals; Bogue et al. (2012) noted the "many shapes and forms" (p. 13) of outreach activities. Four archetypes are described below that illustrate the range of volunteer program sizes, purposes, and approaches.

2.5.2.1 One Professional, Single Presentations

Young (2007) wrote about his experiences making 350 talks over ten years to students. While noting his talks were to elementary school students, it is nevertheless instructive to review the two main benefits he noted: early awareness, and positive role models for students.

His best practices covered topics related to class presentation approaches, topic match to the presenter's interest and expertise; respect for and rapport with students, and use of real-world demonstrations.

2.5.2.2 Sustained Presentations Over Time

Laursen et al. (2007) wrote about a volunteer program still focused on presentations for outreach, but more sustained over time with specific audience/s. It should be noted the presenters were undergraduate students, versus STEM professionals. Nevertheless, it is noted that the volunteer presenters attended monthly meetings and were offered one-on-one coaching to help them make the best connection and impact possible on students.

2.5.2.3 Mentorship Programs

Bruce-Davis et al. (2014) wrote that "high school students may have already developed a passion for a specific discipline and be ready to develop their identities as members of that professional community and receive systematic mentoring from practicing professionals" (p. 275). Compared to other ways volunteers engage, mentorship of students involves more sustained effort from volunteers and more direct engagement with students. Weinberger (1992) described mentorship as "one-on-one commitment by volunteers to improve the self-esteem, attitudes, and attendance of youngsters" (p. 8). Weinberger wrote that mentorship must be done within the context of the school being served. She spoke not only to the educational benefits of mentoring, but also connected mentoring to needs driven by changes in the "character of the American family" (p. 8), and in particular, to the increase in the number of single parent families.

Because mentorship is more in-depth, sustained, direct-to-students, and contextualized by local need, training of volunteers is more in-depth. For example, in CyberPatriot, program coaches are provided regular training sessions, and in turn, they assume a leading role in conducting cyber security training for students (CyberPatriot, 2016a). Examples of mentorship can also be found in FIRST robotics (Veenstra, 2014), engineering-focused programs (Schnittka, Brandt, Jones, & Evans, 2012; Whitaker & Caldwell, 2011), information technology programs (Forssen et al., 2011), physics programs (Watters & Diezmann, 2013), Girls Scouts (Liston et al., 2008), and in formal STEM schools (Scott, 2012). Weinberger (1992) illustrated the time and level of effort required of both mentors and program organizers with these examples: mentor recruiting letters, mentor applications, commitments to attend meetings, coordination with the school being served, and efforts to match mentors with students, not to mention the main goal, which is time spent with students.

2.5.2.4 Large Scale, Organized Programs

At the high end of the volunteer preparation spectrum are medium to large programs, with training programs commensurate in size to the resources available to these larger enterprises. There are a number of such programs, and they are generally run cooperatively by non-profit enterprises with the support of industry. Speaking specifically of engineering-focused efforts, Bogue et al. (2012) wrote that engineering professional societies "reach hundreds of thousands of children, young adults, and volunteers annually…[they] invest an estimated $400 million annually in outreach to address these issues" (p. 12).

Examples of large-scale, organized programs include Project Lead the Way (Veenstra, 2015; Project Lead the Way, n.d.), FIRST robotics (Veenstra, 2015; FIRST, 2016a), Vex Robotics (International Technology Education Association, 2009; Vex Robotics, 2013; REC Foundation, 2016), CyberPatriot (White, Williams, & Harrison, 2010; CyberPatriot, 2015), TEAMS (Tests of Engineering Aptitude, Mathematics and Science) (Technology Student Association, n.d.), and 4-H (Angroaflin, 2014; Kress, McClanahan, & Zaniewski, 2008). Across these programs, there are a number of common activities. STEM professionals visit classrooms to discuss their work and the kinds of problems faced on the job. They engage directly with students, mentoring them individually and in teams, asking questions, and helping with decision making. Their mentorship activities are technical in nature, helping for example with software development and engineering, and are also non-technical in nature, providing guidance in project management, outreach and fundraising. Volunteers train teachers regarding real-world applications, the nature of the workplace, and technical content. Some STEM professionals help run summer camps and competitions. Some professionals, with the support of their employers, host field trips, support job shadowing, and provide internships to students. Their purposes are to drive career interest, provide career education, train teachers, increase student learning, and bring the real world into secondary education.

2.5.3 Studies Focused on STEM Volunteers

One can see the abundance of material in the literature about STEM professional volunteers presenting in schools, helping teachers, discussing careers, mentoring students, and planning and executing large programs. One also sees the questions raised about what is really known about the effectiveness of engaging STEM professional volunteers (National Science Foundation, 2015; Gamse et al., 2014; Bogue et al., 2012; Laursen et al., 2007; Weinberger, 1992). Do studies exist that have attempted to measure the impact of the specific activities of STEM professional volunteers, with an effort to separate their impact from that of other program activities?

The National Science Foundation (NSF) has expressed interest in this question. In their 2013 and 2015 solicitation for the Innovative Technology Experiences for Students and Teachers (ITEST) program, NSF expressed their interest "in projects that examine the effectiveness of engaging adult volunteers with relevant disciplinary expertise from academia or industry to mentor or engage students in school, after school, or out-of-school settings" (National Science Foundation, 2015, Program Description, para. 2; National Science Foundation, 2013, Program Description, para. 7). I reviewed 98 recent ITEST awards whose abstracts were accessible on the NSF web site in May 2015. The projects had start dates between October 1, 2008 and February 1, 2015. The keywords *adult*, *industry*, *volunteer* and *professional* were used to identify awards for further review, and after further review, the keyword *mentor* was noted as prevalent and also searched. The 21 projects listed in Appendix A clearly used STEM professional volunteers, as that term is defined for the current study.

Of those 21 projects, 18 listed no research goals that would shed specific light on the effective of professional volunteers. For the remaining three projects, searches were performed in the academic and general literature to find additional information regarding those projects. Locke, Bracey and Marlette (2014) wrote about an NSF project based on the Botball® Educational Robotics Program (Mayer, Thomas, Locke, Weinberg, & Marlette, 2011). One research goal was understanding which of several mentoring approaches was most effective. The publication clarified that the mentors were teachers, not professionals, and no conclusions were provided regarding preferred mentoring strategies. Keller, Harriman and Szakas (2014) were awarded a project named STEM-C to build computer science teaching capacity in Maine, with a research question regarding how computer science principles drawn from industry examples might help teachers make content relevant for students. A search of the literature did not uncover additional information for this recently started project.

The third example seemed the most direct in addressing questions of STEM professional volunteer effectiveness. Stevens and Andrade (2012) proposed in the NSF-funded *ISTEM* project, targeting Arizona Native American and Hispanic students in Grades 3-8, to compare the effectiveness of three mentor groups: college students, STEM professionals, and members from the participating community, which included the Pascua Yaqui Native American community and tribal members. A review of the project website (Southwest Institute for Research on Women, n.d.) made clear that significant progress has been made on the project. However, at the time of writing, no publications were found in the academic or general literature, and no information existed on the project web site, regarding comparison of mentor groups.

2.5.3.1 STEM Corps Research Agenda

Across all reviewed literature, the most direct study of the effectiveness of STEM professional volunteers was undertaken by Gamse et al. (2014), associated with a National Science Foundation-funded project (Gamse & Martinez, 2013) designed as a "review of the evaluation and research literature on the use of volunteers and/or mentors to build students' interest in STEM" (para. 2), and to create a research agenda with proposed directions and "strength of evidence around key issues" (para. 2). In Gamse et al. (2014), details were shared regarding their methodology, outcomes, and go-forward recommendations. Gamse et al. summarized the state of related research they discovered once engaged in the project:

> The current project set out to identify and synthesize research findings…We planned to build on that first step, through using those findings to propose directions for developing a cohesive research agenda that could guide future programmatic and research endeavors about using STEM volunteers. Our expectation was that we would find substantial published research on the topic, because it is popular and widely discussed. However, after extensive searching and reviewing, it became clear that the research base was less developed than we expected. (p. 3)

Gamse et al. (2014) continued to describe the diversity they found regarding program goals, types of STEM experts, student age ranges, settings, and professionals' involvement and purpose in programs. Even within individual programs, they "could not characterize individual programs as relying upon a single type of STEM expert model" (p. 11). Furthermore, they found that STEM professionals were just one of multiple programs elements. Even when outcomes were measured, they found that ascribing outcomes to the use of STEM professional volunteers would be questionable at best. They chose to move away from development of a full synthesis of the literature, and towards a general literature review that would lead to recommendations for a systematic research agenda. It must be noted that, at this stage, the literature they retained for full review referenced "adults or mentors" (p. 6) that covered a spectrum from K-12 student-mentors to adult community volunteers. The articles retained were restricted to those using "a wide range of adults or mentors" (p. 6) that "explicitly described empirical research about student outcomes" (p. 6). They initially identified 474 articles, and ultimately retained 29 articles for full inclusion in their study. Twelve articles included STEM professional volunteers as that term is defined for the current study.

Like all prior studies discussed in this paper, none of the 29 articles attempted to isolate the impact of STEM professionals, or to isolate the impact of others in a volunteer and/or mentorship role. In the end, Gamse et al. (2014) characterized their study as "early stage or exploratory" (p. 15) as defined by Common Guidelines for Education Research and Development (U.S. Department of Education Institute of Education Sciences and National Science Foundation, 2013). They used what they learned to recommend a systematic research agenda. They recommended four broad research steps: (1) articulate the focus and scope of current practices; (2) develop a theory of action and logic model using hypotheses about practices and impact on student outcomes; (3) investigate the model with exploratory empirical research; and (4) work toward tiered evidence of increasing rigor.

2.5.4 Relation of Current Study to Prior Research

Building on information from Gamse et al. (2014), the ITEST program (National Science Foundation, 2015), and Laursen et al. (2007), the relationship of the current study to this prior research can be described. Both Gamse et al. and Laursen et al. (2007) noted that long-term, controlled, experimental or quasi-experimental studies would be the ideal approach to establish the impact of volunteers, mentors, etc. Both also noted the difficulty of executing such a study. Gamse et al. chose to recommend a systematic exploratory and iterative research agenda. Laursen et al. pushed the research forward based on an existing program whose research was already grounded in formative, long-term observations. Laursen et al. executed a qualitative study targeting affective and attitudinal outcomes.

The current study follows the pattern of Gamse et al. (2014) and Laursen et al. (2007) in adopting an exploratory approach to research. The current study fits within the research agenda proposed by Gamse et al. Their full *step one* recommendation was as follows:

> Articulate the focus and scope of practices involving STEM-trained professional in K-12 educational activities;
>
> a. Identify the common elements across the roles and programs;
>
> b. Articulate the ways in which these practices are unique from other practices. (p. 18)

The current study directly addresses Step 1a. The subsequent section in this literature review provisionally identifies common educator practices from the literature, and the remainder of the study subjects those findings to mixed methods inquiry. Contribution is made to step 1b, based on the practices' identification, and on quantitative study results that do (or do not) show differences between practices, and through explanatory interview data. The current study also makes initial contributions to Gamse et al.'s (2014) research agenda steps 2 and 3, exploring potential relationships between the practices of educators regarding STEM professional volunteers and classroom pedagogical practice.

Beyond the fit with Gamse et al. (2014), the current study complements Laursen et al.'s (2007) qualitative results by introducing quantitative elements, within the context of the current study's larger mixed methods approach. The current study similarly complements the mainly descriptive and qualitative results from prior National Science Foundation ITEST studies. The current study was partly inspired by and is consistent with the ITEST charge to "examine the effectiveness of engaging adult volunteers with relevant disciplinary expertise from academia or industry to mentor or engage students" (National Science Foundation, 2015, Program Description, para. 2).

2.5.5 Coding the Literature for STEM Professional Volunteer Practices

To answer the research questions posed in this study, a list of educators' STEM professional volunteer practices for recruiting and volunteer deployment was needed from which to launch Phase 1 of the study. Therefore, literature was identified, and a coding of the literature was performed. I started by locating literature from which the lists could be created.

2.5.5.1 Summary of Literature Reviewed

Eighty-four articles, including peer-reviewed literature and general literature, were located that described one or more actions taken by an educator regarding STEM professional volunteers. Those articles were identified through three methods. First, some of these articles were already known to me from prior research efforts. Second, a search was performed to locate additional articles accessible via Google Scholar related to STEM education that used the keywords *adult*, *volunteer*, *industry* or *professional*. Third, the same search was performed on articles published in the Journal of STEM Education from 2010 to present. From all articles, 364 excerpts described relevant actions. Table 2.1 summarizes by category the types of articles that were found.

2.5.5.2 Recruiting Practices

There was minimal direct information in the literature describing detailed actions of how STEM professional volunteers are recruited. Selected authors noted the importance of recruiting volunteers. Bogue et al. (2012) called recruiting a "foundational activity" (p. 14).

Table 2.1

Types of Articles Searched

Type	Examples (Article Titles)
Studies Focused on Community or Industry Engagement	• Defining a Research Agenda for STEM Corps: Working White Paper (Gamse, Martinez, Bozzi, & Didriksen, 2014) • Recruiting Future Engineers through Effective Guest Speaking in Elementary School Classrooms (Young, 2007)
Large scale industry support	• Volunteer Guide for Engineers in Support of Educators (American Association of Engineering Societies, 1997) • A Compendium of Best Practice K-12 STEM Education Programs (Bayer Corporation, 2010)
Large scale non-profit support	• Effectiveness of Afterschool 4-H Enrichment Programs (Anglin, 2014) • Engineering is Elementary (Cunningham, 2009)
Studies of specific programs	• Citizen Schools Expanded Learning Time Evaluation: Year 4 Interim Findings (Abt Associates, 2015) • Celebrating 30 Years of K-12 Educational Programming at Fermilab (Bardeen & Cooke, 2011) • Surprising Possibilities Imagined and Realized through Information Technology: Encouraging High School Girls' Interests in Information Technology (Forssen, Lauriski-Karriker, Harriger, & Moskal, 2011)
Colleges and K-12	• Community Colleges Impact K–12 STEM Teaching (Patton, 2008) • What Good Is a Scientist in the Classroom? Participant Outcomes and Program Design Features for a Short-Duration Science Outreach Intervention in K–12 Classrooms (Laursen, Liston, Thiry, & Graf, 2007)
General STEM Studies, Articles	• Mentor and Coach Roles: FIRST® Tech Challenge and FIRST® Robotics Competition (FIRST, 2016f) • An Investigation of Science, Technology, Engineering and Mathematics (STEM) Focused High Schools in the U.S. (Scott, 2012)
Federal or State Government	• Innovative Technology Experiences for Students and Teachers (ITEST): Program Solicitation NSF 15-599 (National Science Foundation, 2015) • 2016-2017 Statewide Strategic Plan for Expanded Learning Opportunities in Texas (Texas Education Agency, 2014)

Afterschool Alliance (2011) noted business as a source of "enthusiastic volunteers" (p. 10). A study by the Center for Adult and Experiential Learning (CAEL) (2011) described building a Mentors 4 STEM program.They stated that "over the course of the 2009-10 school year, eleven former STEM professionals…signed up to volunteer in one of three high schools" (p. 2). This was the extent of information they provided about the recruiting process, a situation observed as typical in the literature. I confirmed this state of affairs by searching for the word *recruit* in the current study's literature base. No additional insights were yielded.

Turning attention to the categories in Table 2.1, I noted the scale of programs operated by large for-profit and non-profit actors (e.g., Bogue et al., 2012; Veenstra, 2015; Anglin, 2014). Many of these programs were accompanied by more formal processes for preparing volunteers for their assignment, and they were inherently connected to larger pools of prospective volunteers. One could also see efforts to centralize/outsource the task of identifying individual volunteers, for example, with Science Buddies (2016), or in the UK's STEM Ambassador program (STEMNET, 2016). Stukas and Tanti (2005) noted the importance of "being asked" (p. 16) as an initiator of volunteer activity in general youth mentorship, an activity for which large organizations hold advantages of scale. The non-profit instances of these programs, while large overall in scale, nevertheless incorporated small, medium and large organizations, and organizations across multiple sectors, including industry, government organizations and non-profits (Olson, 2009; Texas Education Agency, 2014; Pinell, Rowly, Preiss, Franco, Blust, & Beach, 2013; American Association of Engineering Societies, 1997; Weinberger, 1992; Chiu et al., 2015). One might therefore consider the degree to which organizations of different sizes and from different sectors are accessible as sources for volunteers. The technopolis model

(Gibson et al., 1992) is consistent with the idea that recruiting practices might break along lines related to organization size. One might also ask whether educators recruit personally, and/or count on the programs of which they are a part to locate volunteers.

In summary, the literature is mostly silent on the specific techniques educators use to find STEM volunteers. The literature suggests that there are differences between how this activity happens in different sized organizations, and I noted the presence of all sectors in these programs: K-12, colleges, industry, government, and non-profits. The literature also suggests larger scale programs are active in helping find volunteers. These ideas are adopted as a basis for Phase 1 of the current study.

2.5.5.3 How Volunteers are Deployed

As noted in commentary from various literature sources (e.g., Gamse et al., 2014; Young, 2007; Laursen et al., 2007), the literature is rich with anecdotal descriptions of how educators use STEM professional volunteers. Virtually all 364 excerpts previously referenced related to this topic. In light of the large number of excerpts, I decided to code actions observed in the excerpts. The process followed the spirit of coding as described by Saldaña (2009), but was performed independently by me in the larger context of performing a literature review. Forty-four distinct codes were identified. When sorted by frequency of occurrence, it was clear that the top rated codes were general cases (categories) that covered many of the detailed codes which received lower counts. In light of this observation, and knowledge that the paired comparison design of the current study limited the number of actions that could reasonably appear on a survey, I chose to select the most-observed codes as the actions to be evaluated in this mixed methods study. Exceptions were made to include *tutoring*, an area of traditional interest, and also to include *securing resources*, an area where I knew activity occurred in the programs under study. It is noted that this study's Phase 1 was designed to help refine this list of volunteer actions, providing a measure of control against errors I might introduce in synthesizing the literature.

It is further noted that unlike in Gamse et al.'s (2014) selection of literature, no filters related to the rigor of the study or reporting of outcomes were applied. The goal of the literature review was to identify actions performed by volunteers without judging their validity. The current design gives to educators the role of judge regarding which practices are valuable. It is also highlighted for the reader that in many of the projects referenced, volunteers from universities or K-12 were mixed with other professionals. The related studies were retained, even though their volunteer base was not fully consistent with the current study's definition of STEM professional volunteers. Again, the educators in the current study will serve as judges.

Table 2.2 lists the volunteer deployment actions. Also listed are the counts observed during coding. Multiple codes were often associated with single excerpts from the literature.

2.5.5.4 Mentor

STEM professional volunteers acting as mentors tied for the most frequently observed action. Gamse et al. (2014) defined mentors as "role models, coaches, informal or formal educators, or as representatives of individuals who work in diverse STEM content areas, [supporting] engagement with the STEM fields" (p. 3).

Table 2.2

Literature Codes, How Educators Use Volunteers, Count of Four or More

Code	Count
1. Mentor	48
2. Real world	48
3. Careers	33
4. Curriculum	28
5. Projects	17
6. Expert knowledge	15
7. Teach teachers	15
8. Field trips	14
9. Role model	13
10. Teach in classroom	13
11. Present	11
12. Secure resources	8
13. Tutor	4

Mentorship was found to be especially effective in underrepresented populations (Stone, 2011; DuBois, Holloway, Valentine, & Cooper, 2002).While the term is used at times more loosely, mentorship generally indicated a sustained effort to help students with projects, usually with a real-world connection (Bruce-Davis et al., 2014; Morgan, Zhan, & Leonard, 2013; Barker, Larson, & Krehbiel, 2014; Allen, 2013; Liston et al., 2008; American Association of Engineering Societies, 1997; Weinberger, 1992). Mentorship directly impacted outcomes in competitions (Allen, 2013; Bayer Corporation, 2010; American Association of Engineering Societies, 1997) and designed correctly, can impact formal coursework (Recio & Gable, 2007). Dedicated literature on mentorship of students includes Weinberger (1992), *How to Start a Student Mentor Program*.

2.5.5.5 Real World

Regardless of whether volunteers are performing in-depth mentoring or lighter activities, educators frequently looked to volunteers to bring real-world perspective to formal and informal education. The *real world* attribute was observed at the same frequency as mentions of mentoring. Educators were looking for volunteers to help “teachers teach and students learn science the way scientists do – by doing it” (Bayer Corporation, 2010, p. 7). Real-world influence was recognized when there were real work products and students solving real problems (Scott, 2012), teachers receiving help explaining scientific concepts (Change the Equation, 2016; Reynolds, Yazdani, & Manzur, 2013; Fulton & Britton, 2011; Center for Adult and Experiential Learning, 2011), presentations and public portfolios presented (Scott, 2012; Stone, 2011), authentic research performed (Bruce-Davis et al., 2014), connection to the community (Bruce-Davis et al., 2014), and career connections (National Research Council, 2015; Countryman & Olmstead, 2012; Recio & Gable, 2007; Chiu et al., 2015; Stone, 2011). Real-world content drove student enthusiasm and engagement (Watters & Diezmann, 2013; American Association of Engineering Societies, 1997). Not all real-world expertise was technical in nature (Morgan et al., 2013)--for instance, real world examples helped students develop teamwork skills (Watters & Diezmann, 2013). The National Research Council (2015) and National Science Foundation (2015) called for real-world examples to connect to disciplinary content.

2.5.5.6 Careers

Educators placed high value on the career information brought by STEM professional volunteers. Volunteers created awareness of careers in STEM fields (Chiu et al., 2015;

Afterschool Alliance, 2011; Center for Adult and Experiential Learning, 2011; Recio & Gable, 2007). Volunteers helped students understand the relevance of coursework to careers they might choose to pursue (National Research Council, 2015; Goonatilake & Bachnak, 2012; Forrsen et al., 2011; Young, 2007). Especially for underrepresented populations, role models helped encourage students to believe they can succeed in pursuing STEM careers (Gamse et al., 2014; Liston et al., 2008; Forrsen et al., 2007; Recio & Gable, 2007). Students, teachers, and parents were presented with pathways that lead to STEM careers (Gamse et al., 2014; Duran, Höft, Lawson, Medjahed, & Orady, 2014). Perhaps most importantly, the efforts of STEM professional volunteers helped change the perceptions of STEM careers in the eyes of students (Karp et al., 2014; National Geographic Society, 2014; Young, 2007).

2.5.5.7 Curriculum

STEM professional volunteers made direct contributions to curriculum, helping to develop content, and they made indirect impacts on curriculum via educators and curriculum developers (Bruce-Davis et al., 2014; Watters & Diezmann, 2013; Ejiwale, 2012; Center for Adult and Experiential Learning, 2011; Cunningham, 2011; Swift & Watkins, 2004; Jeffers, Safferman, & Safferman, 2004; American Association of Engineering Societies, 1997). Their indirect impacts happened when they shared expertise and ideas, answered questions, and reviewed curriculum drafts (Cunningham, 2011). The real-world content and mindset of volunteers led to constructivist, constructionist, and inquiry-based pedagogical approaches in curriculum (Bruce-Davis et al., 2014; Scott, 2012) and complemented the activities of educators (Morgan et al., 2013; American Association of Engineering Societies, 2011; Fulton & Britton, 2011). Working with educators, real-world content was aligned to content standards (Pinnell et al., 2013). Volunteer efforts helped drive real-world content across schools' curriculum (Carroll & Whalen, 2015; Watters & Diezmann, 2013).

2.5.5.8 Projects

Beyond general inquiry or solving problems as a pedagogical technique, project-based learning (PBL) is present when students are working on defined projects (Markham et al., 2003). Some projects seen in the literature review were explicitly open-ended (Change the Equation, 2016; Cunningham, 2011). Regardless, they embraced inquiry as a technique to gain authentic experiences (Watters & Diezmann, 2013; Daugherty, 2009). Volunteers helped prepare projects and their associated materials (Cunningham, 2011), they designed projects for student teams (Fulton & Britton, 2011; Daugherty, 2009), they advised educators (Liston et al., 2008), and they made data available to support projects (Bardeen & Cooke, 2011; Fulton & Britton, 2011; Edelson, Gordin, & Pea, 1999). Project subject matter seen in the literature covered engineering, IT, software development, manufacturing, and research (Change the Equation, 2016; Gamse et al., 2014; Recio & Gable, 2007; American Association of Engineering Societies, 1997), and even particle physics (Bardeen & Cooke, 2011). Students performing projects benefited from exercising technical and presentation skills (Daugherty, 2009). In general, projects were seen as boosting student interest in STEM topics (Change the Equation, 2016).

2.5.5.9 Expert Knowledge

Frequently mentioned in the literature is the value of STEM professional volunteers bringing expert knowledge to formal and informal K-12 education (e.g., Military Cyber Professionals Association, 2016; Gamse et al., 2014; Liston et al., 2008; Center for Adult and Experiential Learning, 2011; American Association of Engineering Societies, 1997). Bringing expert knowledge was both about sharing that knowledge to help behind-the-scenes, and also for live interactions with students (Gamse et al., 2014; Liston et al., 2008). Liston et al. wrote that "by meeting actual engineers…the [Girl Scouts] could ask questions as they arose and could converse with someone with the intelligence to answer their questions down to the detail. They tended to ask more questions and it generated some awesome discussions" (p. 25). Educators valued expert knowledge shared with them outside interactive class time (Change the Equation, 2016; American Association of Engineering Societies, 1997). An eclectic collection of subject matter areas was noted in the literature, including engineering (Gamse et al., 2014; Jeffers et al., 2004), health science (Burns, 2002), mining, metallurgy, petroleum, and ceramic science (American Association of Engineering Societies, 1997), and wildlife (bears) (Gamse et al., 2014).

2.5.5.10 Teaching Teachers

As just noted, the value of STEM professional volunteers teaching teachers is recognized in the literature. A common activity was volunteers leading or teaching in professional development settings (Moyer-Packenham, Kitsantas, Bolyard, Huie, & Irby, 2009; Patton, 2008; American Association of Engineering Societies, 1997). The audience goes beyond STEM teachers, to guidance counselors and teachers in other disciplines (Patton, 2008). Knowledge transfer also happened through field trips (Page, Lewis, Autenrieth, & Butler-Purry, 2013), reverse internships for teachers in industry (Change the Equation, 2016), and volunteers teaching content directly to students (Bayer Corporation, 2010). Teachers learned about career opportunities (Page et al., 2013; Reynolds et al., 2013; Patton, 2008). In general, teachers valued the professional relationships and collegial support they received from outside the school system (Laursen et al., 2007).

2.5.5.11 Field Trips

The use of field trips to engage teachers and students was regularly mentioned (Goonatilake & Bachnak, 2012; Gamse et al., 2014; Bardeen & Cooke, 2011; Bayer Corporation, 2010; Recio & Gable, 2007; Swift & Watkins, 2004). Field trips can focus on students, and/or on teachers (Page et al., 2013), or specifically on underrepresented populations (Recio & Gable, 2007). The literature suggests that field trips taken by students and teachers provide near-unique exposure and context. Liston et al. (2008), writing about Girl Scout STEM programs, reported that girls experienced “contextual information about what STEM work looks like, where STEM work takes place and who is doing the work” (p. 25). In a descriptive passage about a visit to a water treatment plant, Goonatilake & Bachnak (2012) wrote:

> The participants learned about not only the process and the equipment and materials used for the treatment, but also about the federal laws and requirements to which the plant is expected to adhere in order to produce good quality drinking water. For example, the plant employs a system that combines sensors, seals, and motion detection to protect water from contamination. (p. 16)

2.5.5.12 Role Model

Though sometimes used in a manner related to mentors (e.g., in Liston et al., 2008), the term *role model* was frequently seen in the literature, and carried a different meaning. Mentors were generally engaged over time, while role models described a wider range of volunteers (e.g., Young 2007). Some authors invoking the term were specifically concerned with incorrect stereotypes of STEM fields and workers (Liston et al., 2008), especially in underrepresented populations. Specific mentions of role models were seen in circumstances focused on girls (Liston et al., 2008), African-Americans (Liston et al., 2008), Latinos (Kress et al., 2008), Native Americans (Stevens & Andrade, 2012; Recio & Gable, 2007), and minorities in general (Yelamarthi & Mawasha, 2010). Students as early as elementary school were noted as benefiting from role models (Young, 2007).

2.5.5.13 Teach in Classroom

The actions described above relate to volunteer participation both in and outside formal classrooms. In selected cases, it was clear from the literature that STEM professional volunteers were engaged in formal classrooms during the school day, moving beyond simple anecdotal examples and pursuing goals important to the teacher in their formal classroom instruction (Change the Equation, 2016; Citizen Schools, 2016; Gamse et al., 2014; Cunningham, 2011; Center for Adult and Experiential Learning, 2011). Not unlike informal instruction, formal instruction related to teaching about career education topics, and also about helping students with projects. Scott (2012) noted a case where professionals led special elective courses (and one might assume they were no longer volunteers, but paid for their extended effort). Topics specifically noted where volunteers were directly teaching students in formal classrooms included engineering, software development, and space/aerospace (Change the Equation, 2016; Morgan et al., 2013; Cunningham, 2011).

2.5.5.14 Present

The simplest, shortest term volunteer engagement noted in the literature was guest presentations by volunteers (Gamse et al., 2014; Forrsen et al., 2011; Young, 2007; American Association of Engineering Societies, 1997). The presentations described were focused on raising awareness of STEM-related topics and inspiring students and parents to additional actions. Presenters often shared anecdotes and examples of how STEM content manifests in professional fields and/or in their own jobs (e.g., Forrsen et al., 2011). Also included in talks was technical content related to the subject matter of STEM courses, sometimes through science or technology demonstrations (Forrsen et al., 2011; Bardeen & Cooke, 2011). Another topic noted was preparation for and application to colleges, appropriate for both students and parents (Recio & Gable, 2007).

2.5.5.15 Providing Equipment and/or Tangible Resources

There was some mention in the literature of professional sponsor organizations providing equipment and other tangible resources (physically tangible tools, not simply curriculum guides). Examples include science kits (Bayer Corporation, 2010), data logging equipment (Watters & Diezmann, 2013), computing equipment (Recio & Gable, 2007), science and engineering experiments (American Association of Engineering Societies, 1997), health science supplies (Burns, 2002), and real-world data (Fulton & Britton, 2011). It should be noted that in some cases, while STEM professional volunteers were involved in identifying the resources needed, the resource itself was provided at the organizational level.

2.5.5.16 Tutoring

Less commonly mentioned, but nevertheless present, was evidence of volunteers performing traditional tutoring of students (Johnson, 2012; Center for Adult and Experiential Education, 2011; Recio & Gable, 2007, American Association of Engineering Societies, 1997). It is notable that all four of these references occurred in proximity to the more commonly referenced practices described above. There was no literature reviewed where tutoring was the focal activity of the efforts of volunteers.

2.6 Study Method and Rigor

Mixed methods was chosen as the methodological paradigm for the current study. The rationale for selection of mixed methods design is described below. Established practices for achieving rigor in the design are described, both within individual phases, and across phases, including how the phases reinforce rigor and improve the likelihood of meaningful outcomes. The limits of the current study are described.

2.6.1 Mixed Methods Research

Alexander (2006) wrote about the “methodology wars” (p. 207) between those who advocate for positivism in social science education, with a focus on quantitative inquiry, versus those who advocate for qualitative methods. Citing Dewey and pragmatism (Biesta & Burbules, 2003; Johnson & Onwuegbuzie, 2005; Maxcy, 2003), and also citing Guba and Lincoln (Guba & Lincoln, 1989; Guba, 1990; Lincoln & Guba, 1985), Alexander described the existence of an alternative to positivism, seen in constructivist epistemology and qualitative inquiry. He noted how the U.S. No Child Left Behind (NCLB) legislation declared quantitative research as the “so-called ‘gold standard’ for educational research” (p. 207), but then highlighted the real-world backlash that resulted from this development. Likewise, he challenged the idea that qualitative, constructivist inquiry must be seen as a replacement for positivist inquiry. Rather, he argued for a philosophical foundation that supports quantitative and qualitative inquiry, where “the logic of illustration in educational research [illustrating examples through qualitative inquiry] precedes the logic of generalization [establishing quantitative-based correlation and causation]” (p. 216).

It was previously noted that the current study falls within the research philosophy of critical theory (Guba and Lincoln, 1994). The critical theory perspective maintains ontological realism, but acknowledges the role of social, political, cultural and related factors in creating meaning, and it creates a place for advocacy, transformative impact, and the emergent voice of researchers and participants. Both Creswell and Plano Clark (2011) and Johnson and Onwuegbuzie (2005) noted critical theory as one research philosophy consistent with mixed methods research.

Creswell and Plano Clark (2011) provided a definition of mixed methods research. In their definition, they included collection of both quantitative and qualitative data, use of rigorous collection methods, use of persuasive analytical methods, mixing the two forms of data through intelligent sequencing and/or embedding, and doing all these things framed within philosophical and theoretical perspectives that direct the plan of study. The research questions should drive the necessary detailed decisions about mixed methods research design. Johnson and Onwuegbuzie (2005) stated that “a tenet of mixed methods research is that researchers should mindfully create designs that effectively answer their research questions; this stands in contrast to the common approach in traditional quantitative research where students are given a menu of designs from which to select" (p. 20).

Creswell and Plano Clark (2011) were clear that not all research questions are good fits for mixed methods research. Quantitative methods compare variables and groups, and better support wide execution across a population. Qualitative methods recognize the voices of participants and enable cases where the researcher is also an advocate and/or participant. Mixed methods is a good choice when multiple data sources are needed, results need explanation, or exploration is required to help determine the questions that need to be asked. An often-cited reason to employ mixed methods is to strengthen the research design by protecting against the respective weaknesses of quantitative and qualitative methods (Creswell and Plano Clark, 2011; Jick, 1979).

Creswell (2009) shared four core considerations found across all embodiments of mixed methods designs: timing, weighting, mixing, and perspective. One must determine when to collect quantitative versus qualitative data, and how to sequence or merge data collection to best pursue research questions. The relative weighting of the two types of data must be determined, which also indicates whether quantitative or qualitative methods carry more overall weight in the study. When and how data will be mixed must be determined. One can *connect* data types by using results from one phase to inform launch of the next. One can *integrate* data types by creating quantitative data from qualitative sources (e.g., through coding) and then merging data sets in a thoughtful fashion. One can *embed* one type within another as background support, in a secondary role; for example, qualitative commentary might supplement quantitative rankings. Finally, the philosophical and theoretical lens must be considered, a “transforming lens [that] shapes all phases of the research process in mixed methods research” (p. 208; Mertens, 2003).

Creswell and Plano Clark (2011) defined two types of sequencing especially relevant to the current study. In an *exploratory* design, a qualitative step is taken to explore an area not currently understood or explained by a theoretical framework. The qualitative results connect to the launch of a subsequent quantitative phase. In an *explanatory* design, qualitative research is used to help explain prior quantitative results. For example, one might interview respondents to a quantitative survey to better understand the reasons for their responses. One can also mindfully mix these designs to address the research questions of the study.

It is argued that the criteria for choosing mixed methods are largely met, and that the strengths of the approach outweigh challenges for the current study. The state of understanding of educator practices when engaging employers exists almost exclusively in anecdotal narrative form in the literature. One purpose of this study is to build on those descriptions to arrive at definitions. A qualitative, naturalistic exploration based on findings from the literature will give voice to participants and protect against self-fulfilling interpretations of the literature. Quantitative analysis will bring a check-and-balance to the qualitative exploration, and the quantitative paired comparison and Likert scales fit the specific question of the importance participants assign to different actions. The quantitative CLES instrument, validated in other populations, brings a known schema to the question of pedagogical practice. The final explanatory, qualitative semi-structured interviews further triangulate on the question at hand, and provide an opportunity for member checking of prior results, and clarification of quantitative results.

2.6.2 Rigor in Methods

Mixed methods studies exhibit rigor in three ways. First, the quantitative study elements must be designed and executed for validity and reliability. Second, the qualitative study elements must be designed and executed to achieve trustworthiness. Third, the overall study design must bring the advantages of mixed methods to bear, with the two approaches offsetting the weaknesses of the other (Creswell & Plano Clark, 2011).

2.6.2.1 Quantitative Rigor

In quantitative studies, rigor is achieved through measurement validity, measurement reliability, and study internal validity. Measurement validity and reliability are achieved through the qualities of instruments and surveys deployed. Study internal validity is built through careful execution and management of threats to the study.

Fraenkel, Wallen and Hyun (2012) described three categories of evidence for measurement validity of a specific instrument: content, criterion, and construct. Content evidence exists when an instrument's definition, content, sample of the subject matter domain, format, language and directions are clear from the perspective of the target population. One common approach to building content evidence is to invite subject matter expert review, with that expert chosen keeping in the mind the study's population and setting. Criterion evidence exists when results from the instrument can be positively correlated with results from other instruments attempting the same measure. Construct evidence exists when theory-based predictions can be successfully made based on results from deployment of the instrument.

Measurement reliability refers to the degree to which results are generally consistent over time and/or between subjects. Reliability exists separately from validity—an instrument can reliably make measures, but be measuring the wrong items. Among the techniques for establishing reliability is calculation of Cronbach's alpha (Fraenkel et al., 2012), a reliability measure supported by common statistics packages.

Study internal validity refers to the degree to which relationships between variables are clearly understood, with alternative explanations ruled out (Fraenkel et al., 2012). Threats to internal validity are not just theoretical in nature, but also come from poor study execution and/or external circumstances that affect the study. Fraenkel et al. documented these categories of threats to internal validity: subject characteristics (wrong target for instrument), mortality (loss of subjects over time), location (results influenced by), instrumentation (changes in the instrument or bias in a human data collector), testing (pre-surveys influence later results), history (unexpected influence from an unplanned circumstance), maturation (time passing is the root cause of change), subject attitude, regression (to the mean), and implementation (biased treatment of sample groups).

Pairwise comparison quantitative designs offer specific affordances for establishing study rigor. In particular, the reliability of specific subjects and of specific items can be evaluated using circular triad analysis (Dunn-Rankin, Knezek, Wallace, & Zhang, 2004). A circular triad exists when a particular participant deems A greater than B, B greater than C, but C greater than A, an apparent paradox. While some circular triads are to be expected when human subjects are involved, an excessive number gives cause for scrutiny of the subjects and/or the items measured in the triad.

2.6.2.2 Qualitative Trustworthiness

Lincoln and Guba (1985) identified trustworthiness as the overall goal when developing rigor in qualitative research designs. Trustworthiness was further defined as consisting of these attributes: credibility, transferability, dependability and confirmability. Activities that build credibility include sufficient length of engagement, persistence in observation, peer debriefing (working with colleagues in design and analysis), and member checking (confirming the meaning of participant responses with those participants). Transferability refers to giving the reader the tools needed to determine if study results transfer to the reader's context. A thick description of the research setting, program and execution, and being purposeful in sampling participants via surveys and instruments, contributes to transferability. Dependability refers to the consistent application of research techniques such that data collection and analyses in different locations, in different times, or with different people will lead to consistent results. A watchfulness for unexpected results, and peer review of design, surveys, instruments and artifacts contribute to dependability. Confirmability refers to the ability of others to examine the research and its artifacts, finding sufficient detail to audit results or attempt related research in their context.

2.6.2.3 The Strength of Mixed Methods

The application of mixed methods helps address risks associated with the individual weaknesses of quantitative and qualitative research, a topic addressed in detail by Creswell (2009) and Creswell and Plano Clark (2011). Quantitative research and its interpretation is vulnerable to the hidden biases of the researcher, especially if no efforts are made to identify and/or control these biases. Quantitative research's greater reliance on prior theory leaves less room for treatment of subjects as experts from which new theory will emerge, and creates little room for formal investigation of results based on context.

Qualitative research is at risk of researcher bias--not from hidden bias, but from explicit bias where researcher voice and advocacy is embraced. Qualitative research embraces participant voice, which can introduce bias endemic to participants. Qualitative research is more difficult to generalize, in part due to the limited number of participants studied (Creswell, 2009; Creswell & Plano Clark, 2011).

Both Creswell (2009) and Creswell and Plano Clark (2011) used the term *strand* to refer to qualitative and quantitative elements of the study. The term evokes the idea of strands in a rope, creating a self-reinforcing structure more stable than the sum of the parts. Qualitative research strengthens rigor by creating context and explanation for emerging theory. Qualitative questions embedded in quantitative instruments are a source of formative data that can alert researchers to incorrect assumptions, unclear questions, and unclear directions in surveys. Qualitative research in the final phase of a study can seek to explain and add context to findings. Quantitative phases provide balance in studies where researcher and participant voice (and therefore bias) are embraced. They provide a more rigorous assessment of findings otherwise arrived at through qualitative means. The development of quantitative instruments set up future studies for larger samples, and increase chances for future generalization.

2.6.3 Constructivist Learning Environment Survey

One research question in this study asks about the relationship between educators' volunteer-related practices and the pedagogy they practice in programs using STEM professional volunteers. Assessing this relationship is challenging if teachers' pedagogical self-perceptions do not accurately reflect the pedagogy they practice, a situation reported as common (Ertmer, 2005). The Constructivist Learning Environment Survey (CLES) (Taylor, Fraser, & White, 1994) “enable[s] teacher-researchers to monitor their development of constructivist approaches to teaching” (Introduction section, para. 1). Designed originally for completion by students, it measures constructs related to the presence of constructivist practices in classrooms. By design, it bypasses to the maximum extent possible teachers’ self-perceptions of their pedagogy, attempting to measure pedagogy by the attributes actually present.

Development of the CLES instrument has occurred through multiple phases. An original version of the CLES instrument was found reliable and valid (Taylor & Fraser, 1991); however, its framework supported “only a weak program of constructivist reform” (Taylor et al., 1994, p. 1). Instrument designers wished to overcome objectivist views of science and mathematics. They desired curriculum to be more dynamic and flexible, letting students define their own meaning. The instrument was reworked consistent with the critical theory perspective of Habermas (1984, 1972; Taylor et al., 1994), addressing issues of state control of education, the overriding concern of general welfare of people, and self-awareness and critique of control and context.

The new instrument was reported as reliable and valid in Taylor et al.'s 1994 study (Cronbach’s alpha of 0.79, n=34). Nix, Fraser & Ledbetter (2003) validated the instrument in a study in North Texas, n=1,079, across 59 classrooms. Other studies in diverse locations and settings reported good or better reliability (e.g., Aldridge, Fraser, Taylor, & Chen, 2000; Kim, Fisher, & Fraser, 1999). These studies reflected the participation of students as respondents. Nix (2012) reported that since 1995, the CLES instrument has been used in fifteen studies that included 11,632 students.

The current study used CLES with teachers as respondents. Significantly less evidence is available regarding the use of CLES with teachers as respondents; nevertheless, limited evidence does exist supporting this use. Nix (2012) reported the existence of an adult form of CLES; however, no information was provided regarding differences from the standard form, examples of usage, or results. Johnson and McClure (2004) reported on use of the critical-theory-based CLES with 290 “upper elementary, middle, and high school science teachers and preservice teachers” (p. 65). They reported strong validity and reliability results, with all scales’ reliability (Cronbach’s alpha) reported as 0.80 or higher, and the overall instrument reported at 0.88. DeVellis (2012) categorized alpha between 0.80 and 0.90 as indicating very good reliability. Based on review of factor analysis, factor loading, and reliability analysis results, and also based on follow-up qualitative interactions with teachers, Johnson and McClure created a shorter *CLES 2* form used in subsequent years with teachers. However, not enough teachers participated to complete additional reliability analysis with the revised form.

For the current study, the critical-theory-based CLES instrument was used with educators. The instrument was used to assess the constructivist nature of the educators' teaching, for the programs in which educators are using STEM professional volunteers. While the limited evidence in the literature for using CLES with teachers as respondents is acknowledged, I argue that use of CLES addressed a fundamental challenge, which was educators' generally inaccurate self-perception of their pedagogy. The approach was executed in the best manner possible given the lack of direct access to students. Instrument adaptations were made to further help teachers approximate the perspective of their students.

2.7 Programs and Populations in the Study

The San Antonio CyberPatriot Center of Excellence and FIRST-Alamo Region programs provided the population for the study. The CyberPatriot program provided the majority of participants, while the FIRST-Alamo Region program provided a small number of participants. In the descriptions below, the reader will note similar attributes between the programs, relative to the current study. Because of these similar attributes, it is argued that minimal complexity was introduced into the study, while the additional FIRST-Alamo Region participants helped manage threats to the study and increased in small ways the veracity of quantitative analysis results. Detail is provided for both programs to help the reader determine applicability of the current study to their own context.

2.7.1 San Antonio CyberPatriot Center of Excellence and the CyberTexas Foundation

2.7.1.1 CyberPatriot National Program

CyberPatriot, operated by the Air Force Association, is the National Youth Cyber Education Program (CyberPatriot, 2013a, What is CyberPatriot?, para. 1). The central activity of the national CyberPatriot program is the National Youth Cyber Defense Competition (para. 1). Operated since 2009, the CyberPatriot competition "puts teams of high school and middle school students in the position of newly hired IT professionals tasked with managing the network of a small company…teams are given a set of virtual images that represent operating systems and are tasked with finding cybersecurity vulnerabilities within the images and hardening the system while maintaining critical services" (CyberPatriot, 2013a, The National Youth Cyber Defense Competition, para. 1). Other activities of the national CyberPatriot program include cyber camps and an elementary school cyber education initiative.

CyberPatriot's competition has been on a rapid growth curve. In 2009, the first competition was held with eight teams from the Orlando, Florida, USA area. In the recently completed 2016 competition, 3,379 teams throughout the United States and international locations were registered in the competition's high school Open Division, high school All Service division (JROTC-affiliated teams), and Middle School Division (CyberPatriot, 2016c).

CyberPatriot teams consist of coaches, competitors, technical mentors, and team assistants (CyberPatriot, 2013b). Coaches are educators, school staff members, or other adults approved by a school to be the team's administrative lead. While coaches may bring technical and/or pedagogical expertise, their primary responsibilities are student safety, competition integrity, and serving as the administrative point-of-contact. Each team may have two to six competitors, consisting wholly of either high school or middle school students. Technical mentors are "industry professionals, students, academics, and otherwise IT-experienced adults who volunteer their time to teach cyber defense skills and cyber ethics to CyberPatriot teams" (CyberPatriot, 2013b, Technical Mentor(s), para. 1). Technical assistants are adults who provide non-technical assistance and encouragement to the teams.

Registration fees are charged per team. The Open Division team registration fee is $195.

The All Service division fee is $155, but was waived for most service division teams in the most recent competition year. Scholarships or reduced fees are available for Title I schools, all-female teams, and teams making early registration (CyberPatriot, 2013e).

Training materials and resources are available from the national CyberPatriot program. A competition rule book is provided, and an instructional video is available. Monthly conference calls are held for team coaches to answer questions and discuss relevant topics. Training materials are provided for Windows, Linux and Cisco systems. Specific training modules are provided on multiple topics, including introductory material, cyber ethics, online safety, computer basics, and virtual machines (CyberPatriot, 2013h).

Each year's competition consists of multiple rounds. All rounds except the national finals are conducted online with teams in their home location. In each round, teams have a weekend window in which to complete competition tasks in a contiguous six-hour window. Before the round, teams train using materials provided by the national organization, supplemented with additional training provided by their technical mentors. Teams are instructed to confirm prior to competition that they have the hardware, software and network capabilities necessary to compete. Prior to the round, teams download two to three virtual machine images provided by the national organization that are the basis for the round (CyberPatriot, 2013c).

During each round, teams begin by extracting the virtual machine image and loading it for use. Teams fix security vulnerabilities, complete networking challenges, and answer questions about their actions. These activities score points for the team. Teams can lose points if they take actions that make the virtual machine image less secure. A dashboard can be accessed to view the team's score and standing in near-real-time. Support is available during competitions for technical questions not related to core competition tasks. Scores are reviewed after each round before becoming official (CyberPatriot, 2013c).

The high school competition consists of five rounds. The first two rounds are for qualification and are open to all teams. After the first two rounds, teams are distributed into three tiers. The top 30% of teams enter the platinum tier; the next 40% the gold tier, and the final 30% the silver tier. For each tier, there is a third *state* round and a fourth *regional* round. In each tier, the top three teams from each state round advance to the regional round, along with 36 wild card teams who are selected by being among the top teams nationally. The fifth round is the national finals. The top twelve Open Divisions teams in the platinum tier advance to the national finals; the top two teams from the platinum tier for each service division category advance in the All Service divisions, with categories being Air Force JROTC, Army JROTC, etc. (seven categories total) (CyberPatriot, 2013d).

The middle school competition consists of five rounds. After round 2, the top 50% of teams advance. Round 3 is a practice round. The top three teams nationally from the semifinal round (round 4) advance to the national finals (CyberPatriot, 2013d).

The national finals are held at a central location in the U.S. Teams invited to the national finals are supported all-expenses-paid. Funding for the national finals comes from sponsors and from team registration fees.

2.7.1.2 Center of Excellence and the CyberTexas Foundation

Parallel to the growth of the national program, CyberPatriot regional participation has grown rapidly in San Antonio, Texas, USA (CyberPatriot, 2013f). An enabler of this growth is the long history of activity and accomplishment in the cyber security field in San Antonio. For several decades, San Antonio has been the headquarters for Air Force cyber security operations (Detailed History, n.d.). Within the last decade, Lackland Air Force Base in San Antonio was selected as the headquarters for the 24th Air Force, an element of U.S. Cyber Command). Significant National Security Agency operations have located in San Antonio. The Greater San Antonio Chamber of Commerce reported the city having the second highest number of certified information systems security professional in the United States. Five National Security Agency/Department of Homeland Security Centers of Academic Excellence are located in San Antonio colleges and universities (Zintgraff, 2014). The University of Texas at San Antonio was recognized by practicing cyber security professionals as the leading cyber security Institute of Higher Education in the U.S. (ComputerWorld, 2014).

In February of 2012, the City of San Antonio was named the second regional center of excellence by the national CyberPatriot program (CyberPatriot, 2013f). This recognition reflected the rapid growth of CyberPatriot in the region, the accomplishments of regional teams, and the training program implemented by regional leadership. According to a CyberTexas Foundation Director, Col. (Ret.) Chris Cook, 115 teams competed from the San Antonio region In CyberPatriot VII (2014-2015). In CyberPatriot VIII (2015-2016), 198 teams competed. Regional teams have competed since 2009, and excepting one year, at least one team from the region has qualified for the national finals. In CyberPatriot IV (2011-2012), a team from the Information Technology and Security Academy (ITSA) won the Open Division national championship (CyberPatriot, 2013g). ITSA, founded in 2002, is a partnership between the region’s seventeen local school districts, The Alamo Colleges (the local community college district), and other industry and community partners. ITSA's mission is to educate 11th and 12th grade students in IT and information security.

In 2015, leadership of the regional CyberPatriot effort was formalized in the CyberTexas Foundation. The CyberTexas Foundation's mission is as follows: "San Antonio will lead the way in cyber security. We will steer academic, business, and government entities to develop, promote and enhance cyber and cyber security programs and capabilities" (CyberTexas Foundation, n.d. a, para. 1). The CyberTexas staff includes a program director for high school programs, and a program director for middle school programs. CyberTexas is working with a local school district, Southwest ISD, to implement a full year formal class in cyber security education in middle school (CyberTexas Foundation, n.d. b).

2.7.1.3 CyberTexas Foundation Training Program

Sandi Boyd, a CyberTexas Foundation Director, described the sustained, year-round training program for CyberPatriot participants, both students and adults, conducted by the foundation. Rackspace US, Inc., headquartered in San Antonio, provides facilities, supplementary materials, expert professional staff, and support staff for local high school training events. San Antonio College, an Alamo Colleges campus, provides facilities for middle school training events. A robust number of supplemental training events are organized in support of the national CyberPatriot practice rounds. Training is designed to bring all participants to a solid foundation. Other events through a competition year include a kick-off for each CyberPatriot season, and events supplementing the training of both students and adult sponsors. All training events include exposure to virtual machine images representative of those seen during competition. Col. Cook shared with me the 2016 training calendar, listed in full in Appendix B. Highlights from the program are listed in Table 2.3.

Table 2.3

CyberTexas Foundation Main Training Events for CyberPatriot

Event	Date, Location
CP IX Registration Opens	4/1/16
SA Mayor's Cyber Cup Luncheon College Fair, 10 am Awards Luncheon, 11:30 am	4/2/16
CyberPatriot – Summer of Learning	4/30/16, UTSA
UTSA Cyber Teacher PREP	6/6/16 - 6/10/16
Hallmark University Security+Bootcamps	6/13/16 - 6/24/16, 8/1/16 - 8/12/16
CP IX Exhibition Rounds 1-4, training	April through July
CP IX Prep Clinic (Middle School)	9/12/16 SAC
CP IX Prep Clinic (High School)	9/19/16 Rackspace
CP IX Prep Clinic (Middle School)	10/17/16 SAC
CP IX Prep Clinic (High School)	10/24/16 Rackspace
CP IX HS Prep Clinic (Semi-finals)	1/16/17 Rackspace
CP IX Middle School Practice Round	1/29/17 - 01/31/16
CP IX MS Prep Clinic (Practice Round Semi-finals prep)	1/30/17 @SAC
CP IX Prep Clinic/Red Team	2/27/17 SAC
Finals Practice Round	3/08/17 - 03/18/16
CP IX Prep Clinic/Red Team	3/11/17 IPSecure

The flagship event of the year is the San Antonio Mayor's Cup. Held near the end of each CyberPatriot season, the signature activity is the awarding of the Cup, by the Mayor of San Antonio, to the best-performing CyberPatriot team from the San Antonio region. The winning team receives numerous prizes and cash scholarships from local sponsors. A custom bomber jacket for each winning team member has become the signature award of the event. For the last two years, Hallmark University has awarded full scholarships to all members of the winning team. Other awards are given to high-performing teams. The event is attended by an estimated 1,000 people, including most teams, coaches and adult sponsors. A college fair, and keynote speeches from local industry, community and military leaders, and from the national commissioner of the CyberPatriot program, are standard activities at the event.

2.7.2 FIRST-Alamo Region

2.7.2.1 National Program

FIRST® (For Inspiration and Recognition of Science and Technology) is a national program that uses competitive robotics and STEM activities to inspire students to understand and engage with science, technology, and STEM content (FIRST, 2016a). FIRST operates four programs: FIRST Lego League Jr. (FLL Jr.) (ages 6-9), FIRST Lego League (FLL) (Grades 4-8), FIRST Tech Challenge (FTC) (Grades 7-12), and FIRST Robotics Competition (FRC) (Grades 9-12). FLL Jr. and FLL use small Lego®-based robots. FTC uses larger desktop-sized robots. FRC uses large robots, often as tall as or taller than a standing person.

FIRST was founded by well-known inventor Dean Kamen (FIRST, 2016b). The mission of FIRST is “to inspire young people to be science and technology leaders, by engaging them in exciting Mentor-based programs that build science, engineering, and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership" (FIRST, 2016b, Mission, para. 1). FIRST was founded in 1989. FIRST is "proven to encourage students to pursue education and careers in STEM-related fields, inspire them to become leaders and innovators, and enhance their 21st century work-life skills" (FIRST, 2016b, About FIRST, para. 1; FIRST, 2016c). External study of long-term impacts of FIRST have reported positive results regarding student interest and pursuit of STEM careers (Melchior, Burack, Hoover, & Marcus, 2016).

FIRST operates with two primary values. With *gracious professionalism*, fierce competition is combined with mutual respect and a desire for mutual gain among all teams. With *Coopertition*®, teams help one another and cooperate even as they compete, an approach of mutual respect that also encourages innovation.

Each year, FIRST programs adopt challenges. In the 2015-2016 season, the FLL Jr. and FLL challenges are an exploration of waste and waste management: (1) in FLL Jr., WASTE WISE℠; and (2) in FLL, TRASH TREK℠. For FTC, the 2015-2016 RES-Q℠ challenge is modeled after mountain rescues. For FRC, STRONGHOLD℠ is a challenge game on a live field with the goal of breaching opponent's fortifications.

The FIRST national program maintains training and support materials, and an extensive network of regional organizations and local support resources. Examples of written resources and training materials from the national web site include PDF descriptions of all programs; consent and release forms; an archive of nationally distributed emails to teams; a PowerPoint overview of FIRST and its progression of programs; and volunteer training materials for competition MCs, Game Announcers, Table Supervisors, Table Assistants, Lounge Monitors, VIP and Media Check-in, and others (FIRST, 2016c). A web page exists for searching for local FIRST organizations and regions, of which FIRST-Alamo Region is one (Alamo-FIRST, 2016).

The FIRST national program highlights the importance of volunteers to FIRST programs. Volunteers are referred to as comprising 99.9% of the workforce that operates FIRST. Volunteers include community leaders, employees of corporate sponsors, teachers, parents, university students and faculty, and FIRST alumni and friends. Numerous volunteer positions are non-technical in nature; for example, helping with ceremonies, floating assistants, loading in/out of student teams, and team escorts. Volunteers for the core competition activities include referees, judges, scorekeepers, field managers, and technical staff (FIRST, 2016d). Numerous additional positions are identified in volunteer materials (FIRST, 2016c).

Advance training is required for key volunteer positions. Mentor and coaching roles are specifically described in separate FIRST documents, for FLL Jr. and FLL (FIRST, 2016e), and for FTC and FRC (FIRST, 2016f). FLL Jr. and FLL mentor and coaching roles include facilitation, administration, support for the learning process, and relaying of guidelines and rules to students, teachers, parents and volunteers. FTC and FRC mentor and coaching roles include project management, marketing and finance, and technical roles mentoring students in robot programming/software engineering, electrical engineering, and mechanical engineering.

In the 2015-2016 season, FIRST projected reaching over 400,000 students on over 44,000 teams. A count of 37,000 robots were projected to be built, and 90,000 mentor and adult supporter roles filled. A count of 90,000 additional volunteers were projected in support of events, operations, and local affiliate partners (FIRST in Texas, 2016b).

2.7.2.2 State of Texas Support

In Texas, FIRST receives formal state government support. In the most recent several years, the Texas Workforce Commission has issued approximately US$1 million per year in grant funding supporting FIRST teams (FIRST in Texas, 2016a). In early 2016, FIRST was formally approved as a competitive activity by the state's University Interscholastic League (UIL), the same organization supporting statewide sports, debate, and other academic competitions (UIL, n.d.). FIRST is organized at the state level, with paid staff working to develop activities and competitions statewide (FIRST in Texas, 2016b).

2.7.2.3 Competitions

Patrick Felty and Andrew Schuetze, FIRST-Alamo Region leaders, described FIRST competitions to me. I have also attended competition events. While details vary from year to year, and between programs, competition events follow a general progression. Competition events are the focus of the FTC and FRC (middle and high school) programs. Teams organize with students, educator sponsors, coaches and mentors, and other adult assistants. Based on the season's challenge, teams perform the mechanical engineering, electrical engineering, software programming and testing required to develop a robot and meet the challenge provided. Teams are also responsible for PR, outreach, and other tasks required to operate effectively. Local qualifier competitions are the first opportunities for students to compete. These events are followed by Regional and Super-regional competitions. The season culminates with the world championship event, attended by tens of thousands of competitors and adult sponsors in a large domed stadium setting. Competition is observed by spectators in the stands, in a festive and high-energy, sporting-event-like atmosphere.

A tour of a FIRST competition event is helpful to understand its energy, and its ebb-and-flow. FIRST-Alamo Region has, in recent years, hosted one of four U.S. FRC Super-regional competitions. The competition is held in the city's main convention center, with approximately 2,000 attendees, participants and spectators. The high-energy atmosphere of typical competitions was present at the 2016 Super-regional. Two main competition fields were present. The event started with the national anthems of all countries represented. Spectator stands were full, and a local STEM organization brought a mobile maker-space bus to promote STEM education. Competitions were formally MC'd, announced over loudspeakers at the event. Behind the scenes, *pits* were locations where teams resided between competition sessions, working to solve problems and maintain their robots in top condition for competition.

2.7.2.4 FIRST-Alamo Region Volunteer Training Programs

Training information was shared by Andrew Schuetze. Training programs for educator-coaches are conducted in a conference/workshop format. Events are generally integrated across FIRST programs, including FRC, FTC and FLL. Because the development of robots is open-ended, it is difficult to provide regimented training that covers all topics important to a team, while also avoiding topics unimportant to teams. This characteristic mandates use of the workshop format, with attendees free to choose which sessions to attend. Integration across FIRST programs also allows for topics of general interest to be shared across groups.

Training is provided for both technical and administrative/logistical topics. Technical topics might include robot programming, wiring, or metal assembly. Non-technical topics might include managing a team, or learning the expectations for presenting in a judging room, where teams present their robots and describe elements of their design and group work.

Training events are held two to four times per year. Some training events are held in the San Antonio area. FIRST-Alamo Region organizers also have statewide responsibilities, and some training events are conducted in other areas of the state. One to two events per year are typically conducted local to the Alamo region.

Mr. Schuetze is also familiar with CyberPatriot training. He compared and contrasted the two training approaches. He noted that CyberPatriot competitions are more amenable to regimented training. The more open nature of FIRST robot development makes regimented training more difficult, as requirements are broader and less defined in depth. He characterized the training approaches of the two programs as appropriate to the nature of each program.

CHAPTER 3

RESEARCH METHODS

3.1 Overview

In this chapter, the research methods applied in the current study are described. For each research phase, information is provided regarding how the phase addressed one or more research questions. Information is also provided regarding how the study's methods, techniques and tools were applied to achieve rigor in study execution. The chapter's summary describes how the phases worked together to address the main research question and all sub-questions of the study. In general, this chapter builds on literature review content regarding research methods, research rigor, and the extended descriptions of the programs under study.

3.1.1 Overview of Study Phases

The study was conducted in three phases. In Phase 1, an exploratory qualitative survey was used to sharpen understanding and operational definitions of educators' recruiting and volunteer deployment practices. The survey was completed by a purposeful sample of study participants. The practices put forward in the Phase 1 survey were those derived from the literature. The title of the survey when presented to participants was *Educator Pre-Survey*.

In Phase 2, quantitative methods were used to explore the relative importance of recruiting and volunteer deployment practices in the view of educators, and to explore the relationship of those practices to educators' pedagogical practices in the programs under study. Phase 2 contained two sub-phases. Phase 2a deployed the *Educator Practices* survey. This survey was developed based on the literature review, and refined based on Phase 1 results, toward the purpose of quantitatively assessing the relative importance educators give to recruiting and volunteer deployment practices. Both Likert scales and paired comparisons were incorporated in the survey. Phase 2b deployed the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser, & White, 1994), an instrument validated in other populations, to assess the pedagogical behaviors in the programs under study.

In Phase 3, semi-structured qualitative interviews were conducted to seek explanations for the results of Phases 1 and 2. Phase 3 also pursued deeper understanding of educators' motivations for using STEM professional volunteers. Figure 3.1 illustrates the study's phases.

All surveys and instruments were delivered using the Qualtrics platform available to faculty and students at the University of North Texas. Surveys could be completed on desktop computers, laptops, tablets, or smartphones.

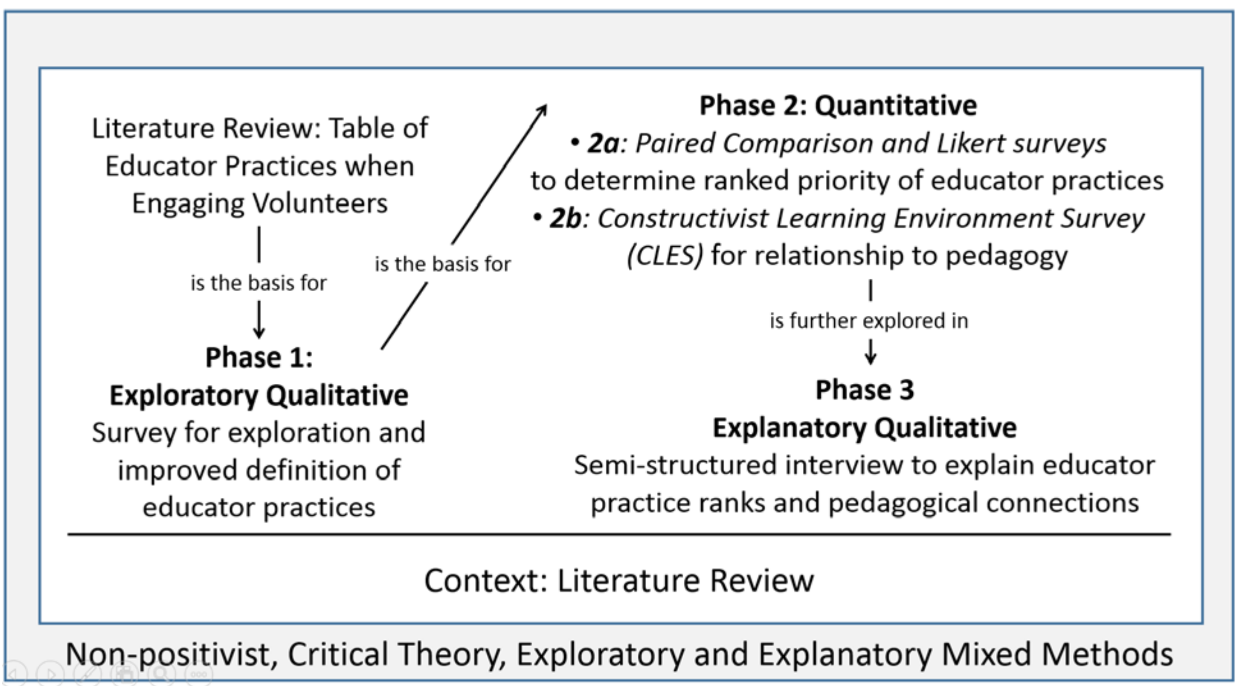


Figure 3.1. Study phases.

3.1.2 Participants

This study's literature reviewed provided extended descriptions of the two programs from which participants were drawn for the current study. Most participants were from the San Antonio-area CyberPatriot program, operated by the CyberTexas Foundation. From a list of 84 possible participants who were current or recent former coaches of CyberPatriot teams, 20 currently active educator-coaches participated in the study. The 20 participants were among approximately 40 coaches active in the current competition year. A number of those participating were recruited by me while introducing the research project at CyberPatriot training events. Further email participation requests from CyberTexas Foundation Directors increased participation. The CyberPatriot directors speculated that the timing of Phase 2 execution, at the heart of the CyberPatriot season and wrapped around December holidays, negatively affected participation.

To protect against study mortality and other internal validity challenges, participants were also invited from FIRST-Alamo Region. The two programs' similarities—both are based on a national program, with local training programs, with many common participating schools, with similar STEM focus, and with some overlap of educators who participate as coaches—provided the rationale for deploying this approach. The approach helped me manage study risks with minimal impact theorized on study fidelity. This risk management approach, considered from the start of the study, was executed when it became clear that fewer-than-expected CyberPatriot educators would participate in the study. FIRST-Alamo Region program leaders promoted the study via email outreach. Four FIRST educators participated in the study, making for a total of 24 study participants.

Participants were recruited consistent with IRB requirements for the study. All participants were adult educators. All participants were assigned pseudonyms, which they used during survey responses. All participants gave informed consent prior to participation in the study. At each contact with a participant, the participant was reminded of the requirement to give informed consent, was asked to re-confirm through a yes/no question, and was given the opportunity to exit should they not agree that informed consent had been given. In surveys and instruments, links were provided to the informed consent web page, which was implemented as a Qualtrics survey. In Phase 3 interviews, notice of recording was given and permission received, and informed consent was verbally re-confirmed.

3.2 Phase 1: Qualitative Exploration of Practices

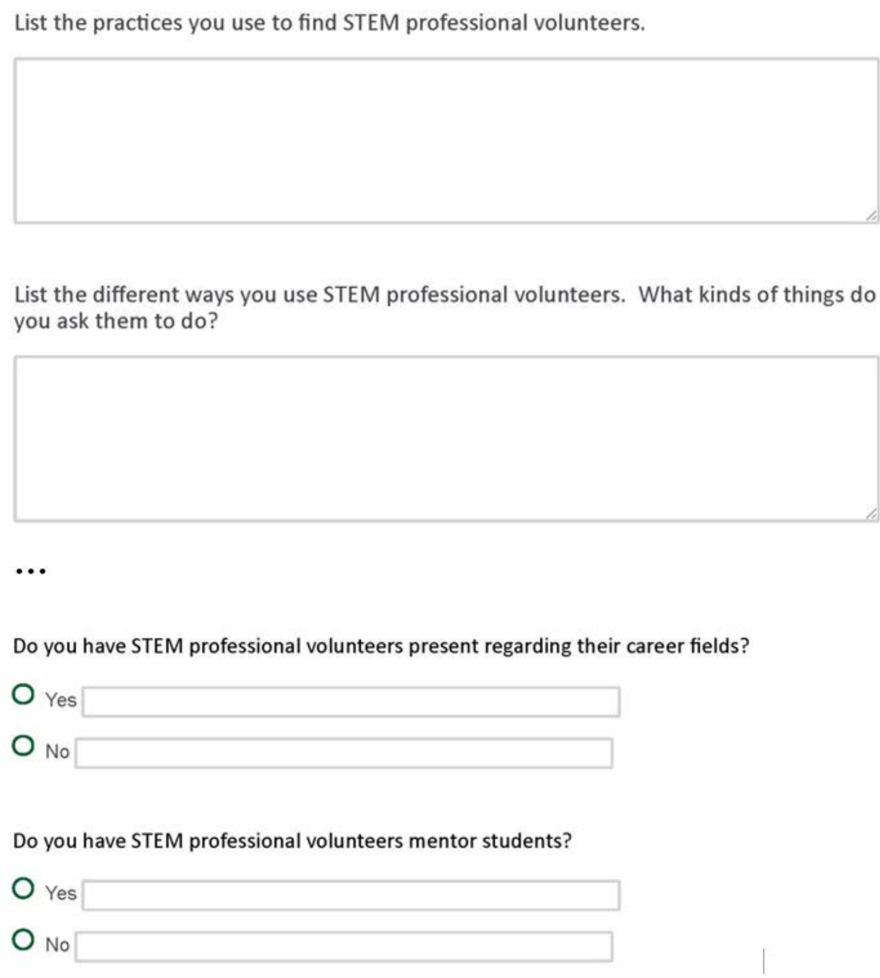
In Phase 1, a small and purposeful sample of participants were asked to complete a mostly qualitative survey designed to confirm current understanding and/or generate new information about educator practices when recruiting or deploying STEM professional volunteers. Five participants agreed to participate, and four completed the Phase 1 survey.

The participants were all from the CyberPatriot program. They were contacted by email to participate in Phase 1, and completed the Phase 1 survey online at their convenience. Participants were chosen during an interactive discussion between myself and my point-of-contact with the CyberTexas Foundation. The point-of-contact was a retired educator, current director on the board of the CyberTexas Foundation, leader of the CyberTexas Foundation training program for CyberPatriot, and a professional with prior industry experience. Using her knowledge of the educators participating, and with consideration of my desire for a purposeful sample, educators were chosen who reflected various school settings and educator demographics. Two of the participants were male and two female. Two of the participants were from small schools, one in a more rural setting, and two of the participants were from large urban school districts. One participant held a leadership role within the larger CyberPatriot program. All were participants who the CyberTexas point-of-contact felt would be responsive to the Phase 1 interview request.

The survey began with fully open-ended questions about what practices participants currently engage in, if any, when recruiting or deploying STEM professional volunteers. Next, the survey presented open-ended questions, but ones more specific to practices uncovered during the literature review. For those practices, participants were asked a yes/no question (the single quantitative measure in Phase 1) regarding whether they engage in the practice, and were provided an open text field to suggest better or more common ways to refer to the practice. The survey closed by requesting additional practices not asked about or previously mentioned by the participant, and it asked for comments regarding the clarity and completeness of the survey. The full Phase 1 survey is found in Appendix C, and a short Phase 1 excerpt is in Figure 3.2.

3.2.1.1 Rigor

Prior to survey deployment, two adult professionals tested the mechanics of the survey and reviewed the clarity of the instructions. One tester was a thirty-year information technology professional, and the second a recent college graduate with a B.S. in nursing, employed as a neonatal nurse.



List the practices you use to find STEM professional volunteers.

List the different ways you use STEM professional volunteers. What kinds of things do you ask them to do?

...

Do you have STEM professional volunteers present regarding their career fields?

- Yes
- No

Do you have STEM professional volunteers mentor students?

- Yes
- No

Figure 3.2. Excerpts from Phase 1 survey.

They found the survey to be clear with no significant recommendations for improvement. However, preparation for the test drove me to review and reflect on the questions, in the context of the literature review. Edits were made separating (1) volunteers helping with projects from (2) volunteers helping with coursework. Also, an edit was made to specifically use the word *curriculum* in the question about STEM professional volunteers helping educators develop content for coursework. The order of questions in the Phase 1 survey was intentionally designed to protect against self-confirmation bias. In creating this design, I kept in mind the writings of philosophers like Bernstein (1995) and Habermas (1984), who argued that the framing of questions can bias responses. This challenge was addressed by starting with the most open-ended questions, using the simplest and most general language possible, and then working toward more detailed and potentially leading questions. Respondents were specifically instructed not to adjust earlier answers based on later questions in the survey. While it is not possible to fully mitigate bias during discourse, I attempted to minimize bias by setting the minimum context necessary to engender relevant answers to questions. Ultimately, specific questions were asked, consistent with the critical theory paradigm of the study.

Significant features of the survey were designed to surface problems during execution. For each question targeting a specific recruiting or volunteer deployment practice, an open text field allowed comments regarding meaning and clarity. At the end of the survey, a specific question asked about the clarity of the overall survey. Responses indicated that participants found the survey to be clear and complete regarding the topic of study.

Phase 1 contributed to the overall trustworthiness of the study. Trustworthiness was enhanced by increasing the length and depth of engagement and the persistence of observation. Phase 1 engaged participants as colleagues, effectively executing a peer debrief regarding survey and study content. This full description of Phase 1 enhances confirmability and transferability.

3.2.1.2 Analysis Method

Descriptive statistics were generated for the yes/no questions. Constant comparative coding (Saldaña, 2009) was applied to analyze open-ended question results. Coding was performed for the purpose of sharpening the list of practices that will be explored in Phase 2 research. A second coder and I restricted codes to items related to the study's research questions, but within that context, the emic (emergent) method was adopted. Codes were not limited to the theoretical answers expected from the respondents.

The coders were myself and an educational technology professional with prior experience assisting Ph.D. candidates with dissertation efforts. The second coder was familiar with the coding process, but was re-trained to ensure familiarity with the process as described by Saldaña (2009), and for familiarity with a spreadsheet tool for coding developed by me. Codes were determined independently, and an in-person meeting was held to resolve differences. The coders intended to generate categories and themes, but discovered during the process that the codes were at the proper level of abstraction to make the contribution desired for Phase 2. An effort to generate categories and themes made clear that such effort was premature and best saved for Phase 3 explanatory efforts.

3.3 Phase 2: Importance of Practices, and Pedagogy in Program

Phase 2 involved the development, deployment and analysis of an Educator Practices survey, and the use of the Constructivist Learning Environment Survey (CLES) instrument (Taylor et al., 1994) to identify pedagogical practices in the programs under study. The Educator Practices survey was used to quantitatively investigate the importance of recruiting and volunteer deployment practices to teachers. The Educator Practices survey applied three quantitative techniques: Likert scales, pairwise comparison, and collection of general information and demographics for generation of descriptive statistics. The general information collected was based on topics raised in the Phase 1 survey. The CLES instrument was used to identify pedagogical practices in the programs under study, which were in turn used to explore relationships to recruiting and volunteer deployment practices. Figure 3.3 shows excerpts from the Educator Practices survey, and Appendix D contains the full survey. Figure 3.4 shows excerpts from the CLES instrument, and Appendix E shows the full instrument.

Speak to students about careers.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Mentor students.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

--

Which practice is most important to you? Choose one from each pair:

○ Speak to students about careers
○ Mentor students

○ Help students with projects
○ Speak to students about careers

Figure 3.3. Likert and paired comparison excerpts, Educator Practices survey.

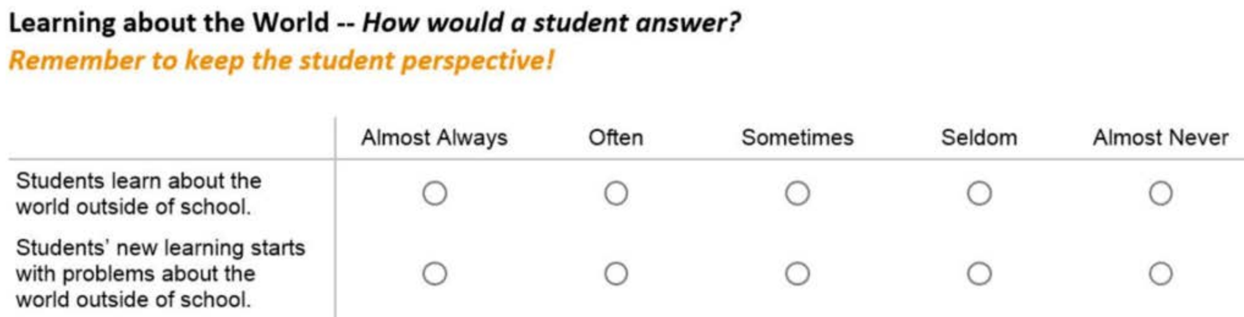


Figure 3.4. Excerpt from CLES instrument.

3.3.1 Educator Practices Survey

3.3.1.1 Pairwise Comparison

Pairwise comparison is an effective way to assess relative importance of practices while incorporating mechanisms that address study rigor. The pairwise comparison tool used variance stable rank sums analysis, a non-parametric method for ranking psychological objects (Dunn-Rankin et al., 2004). This analysis resulted in a unidimensional scale (a line graph) on which the recruiting and volunteer deployment actions are placed, using a measure between 0 and 100. This line graph is an easy-to-understand visual illustration of the results of the paired comparison. With sufficient sample size, statistical significance can be established between objects on the unidimensional scale.

The pairwise comparison included as psychological objects all practices emerging from Phase 1. All practices were operationally defined, with those definitions provided to participants at the start of the survey. Practices were presented two at a time. Participants indicated which of the two practices they found most important. Importance was defined as follows: *If a practice is important to you, you spend time on it, you prioritize it compared to* *other things you might spend your time on, and you find value in the outcomes of the practice*. Additional clarification was provided, and can be seen in the full version of the survey located in Appendix D. It was originally planned that participants would be asked to compare each practice to all other practices.

3.3.1.2 Dynamic Survey Changes/Addition of Likert Scales

The originally proposed research methodology used only pairwise comparison to assess practice importance. During study execution, changing circumstances required modifications to the study design. In this study's critical theory and mixed methods approach, the precise number of practices to be compared was not known until completion of Phase 1. The number of practices grew as a result of Phase 1, and also as a result of new literature identified. Pairwise comparison surveys grow geometrically in size as additional items to compare are added. A count of 121 paired comparisons would have been required to compare all combinations of recruiting practices, plus all combinations of volunteer deployment practices (12 recruiting practices and 11 deployment practices, each requiring $n*(n-1)/2$ comparisons). This was deemed burdensome for the participants, and a mortality threat to the study.

A second consideration arose, one concerning the interaction between number of practices being compared, the number of participants, and the potential for statistical significance. Originally, I expected close to 40 participants. Dunn-Rankin et al. (2004) listed, for each number of psychological objects (practices) being compared, the number of participants required to have potential for statistically significant differences. As informed consent notices were received, it became clear that 20 participants was a more reasonable expectation. This number of participants supported pairwise comparison of four actions or less to leave open the possibility of statistically significant differences. It is acknowledged that in the current study design, statistical significance is not generalizable. Nevertheless, I took the position that overall mixed methods study rigor is improved when quantitative design and deployment enables the possibility of statistical significance.

A strategy for mitigating both of the concerns listed above is to create subgroups of practices for pairwise comparison. Fewer practices require geometrically fewer comparisons to fully cross-compare; even after creating pairwise comparisons for all subgroups, many fewer comparisons were required in total than for a single large group. In addition, with fewer practices, greater potential for statistically significant differences is created.

The primary disadvantage of subgroups is the loss of comparison data. For example, if *recruiting parents* is in a separate group from *recruiting from startups*, then no comparison data between the two items will exist. It was recognized that adding a Likert scale for *all* practices would re-introduce the ability to compare across subgroups. Pairwise comparison and Likert scales could also form a type of internal criterion validity, with the two methods to cross-checking measurement validity. A final benefit would be the option to use Likert results to analyze relationships between practices and the pedagogy in the programs under study.

With all factors considered, I made the following decisions: to create recruiting subgroups, to create volunteer deployment subgroups, to use the subgroups for pairwise comparison, to add a Likert scale question set measuring all recruiting practices, and to add a Likert scale question set for all volunteer deployment practices. This new approach resulted in

66 total questions regarding the importance of practices, cutting the number of questions approximately in half.

I applied my judgment, framed by the literature review and Phase 1 results, in creating the subgroups. Three recruiting subgroups were created, with four actions each: *recruiting through local resources* (for example, one's personal network), *recruiting from different sectors* (for example, industry versus government), and *recruiting from industry*, comparing different-sized industry organizations. I recalled literature regarding the involvement of different-sized organizations and different sectors, and also considered how the Phase 1 participants contributed the ideas of recruiting former students and parents, in creating these subgroups.

Two volunteer deployment subgroups were created, with six and five items respectively: *working directly with students*, and *supporting educators*. The sole rationale for these two subgroups was my recognition of the dichotomy that existed in the list. Some practices placed volunteers in front of students, and some did not.

For the deployment subgroups, the subgroup size was still larger than the four-item maximum recommended for a pairwise comparison with 20 participants. Nevertheless, with this overall design, it is argued that a balance was achieved. The balance was between the burden on respondents, mortality concerns, and the rigor of individual elements of the study.

Finally, with Likert scale data being the one measure comparable across all practices, it became the natural data set for seeking correlations to pedagogical practice. Plans were adjusted accordingly. Details accompany later information on the CLES instrument.

3.3.1.3 Demographics and General Information

This survey collected demographics and general information; in particular, it collected information on topics raised by participants in Phase 1 not related to specific practices. Several questions were included asking educators if they have a sufficient number of volunteers in their programs, and how locally available resources might satisfy that need. Educators were asked about the size of their schools, and whether they work in a Title I school.

3.3.1.4 Rigor

The Dunn-Rankin et al. (2004) analysis tools support circular triad analysis. A circular triad is a set of three or more rank scale responses where the same participant rates A greater than B, B greater than C, but C greater than A. An excessive number of circular triads by one respondent strongly suggests that a non-serious or confused survey response was provided and should be eliminated from consideration. In addition, a large number of circular triads involving a specific psychological object (practice) across many respondents suggests that the object was not clearly understood by participants. If caught during survey review, operational definitions can be improved, or the term used for the object improved. If discovered after distribution to participants, the object might be excluded prior to analysis. The overall robustness of the Dunn-Rankin et al. approach and implementation of pairwise comparison, and validation of their results, can be assessed in their book on scaling methods (Dunn-Rankin et al., 2004).

The pairwise comparison survey was tested prior to use with a small set of participants. A thirty-year information technology professional tested the mechanics of the survey. Two errors that might affect interpretation of questions were corrected. Two study participants then reviewed and commented on survey content. While I would have preferred to recruit non-participants for review, circumstances led to these participants being accessible when needed, with the right knowledge to provide an informed review. I made the decision that, going forward, the study would benefit more from inviting their Phase 2 responses than from excluding their continued participation.

At the end of each section of the survey—the recruiting section, the volunteer deployment section, and the demographics section/overall survey wrap-up—participants were asked in open-ended text to describe any survey element that was not clear. There were eight responses for the recruiting section, six for the volunteer deployment section, and two responses to the demographics/overall survey question. Most responses indicated the survey was clear. One participant noted they felt a number of the pairs were tied, and wished that choice was provided as a response option. No other specific recommendations for improving the survey were made. Three recruiting responses and two volunteer deployment responses re-purposed the field to share background or ideas about STEM professional volunteers. These responses were consistent with later interview results from Phase 3.

In the final analysis, quantitative rigor is determined by measurement validity, measurement reliability, and study internal validity (Fraenkel et al., 2012). Measurement validity (does the survey measure what it is intended to measure?) is supported by the literature foundation of the survey, and the Phase 1 confirmation of content with subject matter expert-participants, and by high similarity between paired comparison and Likert results. Analysis of circular triads contributes to measurement reliability by eliminating unreliable responses. Study internal validity is affected by study execution and external circumstances. Of the concerns listed in the literature review, subject characteristics and mortality were of greatest concern. Subject characteristics was addressed through the involvement of subjects as participant-experts. Mortality was addressed as previously described regarding managing the risks of low participation, and by making the requisite adjustments to research methods.

3.3.1.5 Analysis Methods

The RANKO and TRICIR software provided by Dunn-Rankin et al. (2004) was used to analyze pairwise comparison data. All Likert scale data were imported into Microsoft Excel for general review and analysis purposes. Summary calculations were performed in Excel to generate descriptive statistics for general questions and demographics categories.

3.3.2 Constructivist Learning Environment Survey (CLES)

Taylor et al. (1994) designed the CLES instrument to determine whether a constructivist learning environment exists in a classroom. Five scales are contained in the instrument that measure the degree to which students experience personal relevance, can express critical voice, can exercise shared control over their learning, are allowed to experience uncertainty, and can practice student negotiation in classrooms regarding their learning. As noted in the literature review, many researchers reported that adult volunteer engagement and/or the associated experience of in-classroom technology usage best happens in the context of constructivist pedagogy (Ertmer et al., 2012; Edelson et al., 1999; Hmelo-Silver et al., 2007).

3.3.2.1 Framing CLES Use

CLES was used in the current study for two purposes. First, it was used to confirm that, from the educators' perspective, for the programs under study, constructivism was present, if not the dominant educational philosophy in use. Second, CLES results were used to seek relationships between the pedagogy reported in the programs under study and educators' answers regarding recruiting and volunteer deployment practices. These relationships were sought by looking for statistical correlations between (1) recruiting and volunteer deployment practices as reported in Likert scales, and (2) CLES scale results.

3.3.2.2 Adaptations

The CLES scale measuring *experiencing uncertainty* contains questions about uncertainty in science. While those questions might have been adapted to relate more specifically to information technology and/or cyber security, I judged that the complexity introduced outweighed potential benefits. Therefore, the scale was omitted, with the added benefit of shortening the survey and slightly reducing participant burden.

3.3.2.3 Rigor

The retained CLES scales were administered and tested for reliability and validity within the test population. Reliability assessment was made using the categories identified by DeVellis (2012), where Cronbach's alpha for each scale falls in a range designated as unacceptable, undesirable, minimally acceptable, respectable, very good, or so good that the scale is a candidate for shortening. Reliability of the scales were *very good* or above. While this cannot establish measurement validity, this result was consistent with measurement validity. (Phase 3 interviews further suggested that the participants found the CLES scale questions to be sensible in their setting.) Regarding study internal validity, the same concerns were identified as for Phase 2a, subject characteristics and mortality, and they continued to be addressed as previously described. Figure 3.4 shows an excerpt from the CLES instrument. Appendix E contains a full version of the CLES online instrument used during this study.

3.3.2.4 Analysis Methods

Scale reliability was measured as noted, using the scale reliability tool in SPSS. Correlations were sought to Likert scale scores using tools in SPSS. CLES's measurement validity in the view of participants was further evaluated through qualitative means during Phase 3 interviews. Interview questions were asked which shed light on the participants' understanding of CLES scale items.

3.4 Phase 3: Qualitative, Explanatory Semi-Structured Interviews

Explanatory mixed methods is a study design where qualitative techniques follow a quantitative phase, in an effort to explain quantitative results (Creswell & Plano Clark, 2011). In the current study, a final set of semi-structured interviews were performed for the purpose of better understanding the ranking of educator practices, and for better understanding the reasons behind relationships discovered between those actions and the pedagogy reported present in program classrooms and settings. Drever (2003) described semi-structured interviews as having general structure, with advance determination of main questions, but details left to be determined during interviews. Figure 3.5 contains an excerpt from the Phase 3 script used during semi-structured interviews. Appendix F contains the full survey and a handout provided to the participant.

1. You rated RecruitFormerStudents at <N>. Why?
    - Why (higher/lower) than others?
2. You rated RecruitParents at <N>. Why?
    - Why (higher/lower) than others?
3. In general, recruiting through local/personal/program resources was higher than recruiting industry, government, non-profits. Why?

Figure 3.5. Excerpt from Phase 3 semi-structured interview script.

A purposeful sample was selected that included both typical respondents and outliers. Outliers in particular can be sources for the best explanatory insights (Bazeley, 2009). Four requests were made for Phase 3 interviews, and three participants agreed to participate. The three participants respectively fit profiles of generally high raters, medium raters, and low raters, referring to the scores they indicated on their Phase 2a Educator Practices survey. Participants were interviewed through phone calls via Skype and recorded using MP3SkypeRecorder. Recordings were transcribed using the web service TranscribeMe.com. All three participants scheduled the interview during a teacher work period in their school day, and accepted the call while physically located in their classroom.

3.4.1 Rigor

Phase 3 was designed to build trustworthiness through the four attributes of credibility, transferability, dependability and confirmability (Lincoln & Guba, 1985). Credibility was enhanced by the continued and persistent observation from Phase 1 through Phase 3, by treating the participants as colleagues (the interview was an effective peer debrief), and through the member checking process of sharing and confirming transcript content and meaning with Phase 3 participants. Transferability was further built through the thick description provided of Phase 3, and through the purposefulness exhibited in selecting participants. Dependability was further built through consistent application of interviewing techniques for the three Phase 3 participants, and through watchfulness for unexpected information. Confirmability was further built by providing the artifacts of research.

3.4.2 Analysis

Constant comparative coding (Saldaña, 2009) was used to analyze the Phase 3 transcripts. Coding in this phase applied an etic approach (Pike, 1954) within the context of Phase 1 and 2 results. The focus of coding was to explain Phase 1 and 2 results.

3.4.3 Summary of Research Method Details

Table 3.1 provides a succinct summary of the research methods applied. The table lists the phases and the associated surveys, instruments, and analysis techniques applied. Selected approaches to survey rigor are also listed.

Table 3.1

Research Phases, Surveys, Instruments, and Rigor

Phase / *Purpose*	Surveys	Instruments	Analysis	Rigor
1. Exploratory qualitative (Creswell & Plano Clark, 2011) Refine educator practices	• Educator Pre-survey		• Constant comparative coding (Saldaña, 2009) • Identify practices; identify other themes	Trustworthiness: • Pre-test of survey • Start with strongly-open-ended questions • Start of persistent observation • Watchfulness in results
2a. Quantitative Rank educator practices	• Educator Practices Pairwise comparison; Likert; demographics and general info		• RANKO and TRICIR (Dunn-Rankin et al., 2004) • Likert descriptive statistics	Reliability and validity: • Pre-test of survey • Circular triads • Built-in watchfulness • Building measurement validity, reliability, study internal validity
2b. Quantitative, CLES ID pedagogical practices in programs		• CLES (Taylor et al., 1994)	• CLES scale reliability • Correlations of Likert to CLES	Reliability and validity: • Pre-test of survey • Scale reliability • Built-in watchfulness • Building measurement validity, reliability, study internal validity
3. Explanatory qualitative (Creswell & Plano Clark, 2011) Explain rankings and relation to pedagogy	• Semi-structured interview		• Constant comparative coding (Saldaña, 2009)	Trustworthiness: • Constant comparative coding • Last step of persistent observation • Ongoing watchfulness

3.5 Summary

In this chapter, the research methodology executed for this study was described. This included an illustration of the study phases, a general description of the participants, an overview of the research phases, and a detailed description of each phase. For each phase, described were steps taken to achieve research rigor, how data analysis was planned, other relevant details about how the phase was positioned within the overall study, and any adjustments made from the proposal stage to execution of the study.

All phases addressed the overall research question, exploring how secondary educators relate to STEM professional volunteers. Phase 1 addressed the two sub-questions regarding the practices of educators when recruiting and deploying STEM professional volunteers, by refining the list of practices and addressing operational definitions. Phase 2a addressed the same sub-questions by exploring their relative importance according to this study's participants. Phase 2b addressed the third sub-question, exploring relationships between educator practices and the pedagogy present in programs. Phase 3 qualitatively explored all three sub-questions, pursuing explanations, and it also pursued the fourth question regarding the deeper reasons educators pursue relationships with STEM professional volunteers.

In the current literature base, content on this topic is dominated by anecdotal examples. The most rigorous study on this topic to date recommended an exploratory research agenda (Gamse et al., 2014). Through the methods described above, that exploratory agenda was pursued. Results are described in the following chapter.

CHAPTER 4

DATA COLLECTION AND ANALYSIS

This chapter describes the results of data collection and analysis for the current study. For each phase, the number of participants, a summary profile of the participants, and data collection results is shared. Results include descriptive statistics, qualitative analysis and inferential statistics appropriate to the data being described. To the extent the study design was adaptive based on results from prior phases, a description is provided of how each phase's data collection was affected by activities in the prior phase.

4.1 Overview of Data Collection and Analysis

Table 4.1 provides a quick overview of data collection and analysis activities. It indicates the number of participants in each phase. It also describes in concrete terms the types of results available from each phase.

4.2 Phase 1, Exploratory Qualitative, Educator Pre-Survey

4.2.1 Qualitative Coding of Practices

A count of N = 4 participants completed the Phase 1 mostly qualitative pre-survey shown in Appendix C. The survey, whose content was derived from the literature review, was analyzed via constant comparative coding (Saldaña, 2009). Given the relatively small number of codes generated, and the fact that the codes were already at the correct level of abstraction to influence content of the Phase 1 survey, categories and themes were deemed outside the scope of Phase 1 and were not generated. Table 4.2 lists the recruiting codes generated, and Table 4.3 the deployment codes generated, both sorted by those most commonly observed.

Table 4.1

Summary of Types of Results by Phase

Phase	N	Results
1, Qualitative, Educator Pre-survey	4	Codes for educator practices Yes/no counts for each practice
2a, Quantitative, Educator Survey	24	Demographics and general info Recruiting practices: • Unidimensional scales by importance o Recruiting through local resources o Recruiting from different sectors o Recruiting from different-sized industry organizations • Likert ranking by importance Volunteer deployment: • Unidimensional scales by importance o Directly working with students o Behind-the-scenes support for educators • Likert ranking by importance General, non-practice-specific questions
2b, Quantitative, CLES Instrument	23	CLES scale reliability measures Notable correlations, educator practices to CLES scales
3, Explanatory qualitative, semi-structured Interview	3	Codes, categories and themes based on questions related to ranking of recruiting practices, ranking of deployment practices, and practice-to-pedagogy correlations

Table 4.2

Phase 1 Survey, Constant Comparative Coding, Recruiting

Code	Educators…	Count
Networking	talked to people they knew, and to new people they met, both local to them and when moving outside the school (local events, conferences).	5
Program-prepared outreach materials	reached out to potential volunteers using materials prepared by the host program.	2
Parents through students	contacted parents, through students, to ask them to volunteer.	2
Through host program	used volunteers secured by the host program.	2
Personal contacts	found volunteers through their personal contacts.	2
Word-of-mouth	had volunteers come to them through word-of-mouth.	1
Parents offer	had parents proactively offer to volunteer.	1
Conferences	found volunteers at conferences.	1
Former students	recruited former students to volunteer.	1
Defense/cyber	recruited from active duty military units.	1
Large corporations	found volunteers at large corporations.	1

Table 4.3

Phase 1 Survey, Constant Comparative Coding, Deployment

Code	Volunteers, at the request of educators, …	Count
Real world	brought real-world knowledge, success stories, authenticity, career options into classroom.	6
Careers	spoke to or taught students about career options and/or pathways to careers.	6
Content knowledge	brought important detailed/technical knowledge for the program; taught knowledge the teacher does not have to students.	4
Mentor	filled knowledge gaps, answered student questions, taught content not known by teacher, helped with their work path.	3
Operational assistance	equipment setup, maintenance.	3
Resources	found and/or paid for a needed resource.	1
Live support	answered student questions live/in-person.	1
Desire for field trips	indicated desire to add field trips to program.	1
Professional development (PD)	delivered professional development.	1
Desire for PD	Educators indicated desire to add PD.	1
Open to direct instruction	Educators indicated openness to volunteers giving direct instruction in formal settings.	1

4.2.2 Yes/No Question Counts

Supplementing the qualitative questions, a yes/no question was asked for each practice regarding whether the person responding performed the practice. Table 4.4 lists the yes/no question counts. Shorthand descriptions of the questions are used for readability. Appendix C contains the full survey.

Table 4.4

Yes/no Question Counts from Phase 1 Survey, Sorted by Positive Response

Related to	Phase 1 Question	Yes	No
Recruiting	Through your own organization or program	4	0
	Personal contacts	4	0
	Small-but-established companies	3	1
	Large companies	2	2
	Medium-sized companies	1	3
	Startup companies	0	4
Volunteer Deployment	Present regarding their career fields	3	1
	Help students with specific projects	3	1
	Help you understand application of content in their workplace	3	1
	Mentor students	2	2
	Help you develop curriculum	2	2
	Host fields trips	2	2
	Tutor students in traditional coursework	1	3
	Deliver teacher professional development, and/or host you at their workplace	1	3
	Deliver instruction in formal settings (e.g., in your classroom)	0	4

4.2.3 Comments on Clarity

Comments were invited for each specific practice that was proactively investigated. The invitation was for comments regarding: (1) the clarity of the Phase 1 survey question, and (2) observations on phrasing, meaning, and whether the question was asked in a common and familiar way. No responses addressing those topics were provided, which was interpreted as broad agreement that the questions were clear and asked in familiar ways. Participants occasionally re-purposed those fields to provide details about their answers, but no responses resulted in codes beyond those of the practices already listed.

In the question dedicated to asking about the clarity of the overall survey, three participants specifically noted the questions were clear, and the fourth re-purposed the field in the same manner as noted above. In the dedicated question asking about additional practices not previously mentioned by the survey or participant, one participant wrote “engage in projects with mentors and report progress.” Both coders noted the overlap with Question 14 in the survey, which specifically asked about projects. However, in hindsight, this response may have been the first indication of questions about the meaning of *projects* in this study.

4.2.4 Analysis

Two practices received no affirmative yes/no responses: recruiting from startups, and delivery of instruction in formal settings (like classrooms). Caution was exercised in removing items based solely on responses to a qualitatively designed survey taken by four participants. For the recruiting of startups question, I determined that the topic is within the scope of the research questions and required for completeness of the industry recruiting questions. For the question regarding instruction in formal classrooms, I noted from my own experience that educator-coaches sometimes bring volunteers into elective classes to teach regarding the program they support. A judgment call was made to also retain this question in Phase 2.

It was observed that selected volunteer deployment codes are not practices, but rather are attributes, and/or are captured via other practices. The *real world* code, while obviously important in concept, did not represent a specific educator practice one could ask participants to rate; however, mentorship is a practice, as is teaching content knowledge, teaching about careers, and helping educators understand real-world content, all of which are rooted in professionals' real-world experience. Likewise, the *live support* (for students) code is an action that happens during mentorship. The *real world* and *live support* codes were not carried forward as independently rated practices.

One code indicated recruiting from the government (military) sector. This code highlighted a shortcoming of the recruiting Phase 1 survey, not only regarding recruiting from the military, but also recruiting from sectors outside industry, consistent with the technopolis model of regional cooperation when building technology-driven economies (Gibson et al., 1992). It was determined to add questions about recruiting from government and non-profit sectors. Higher education is also one of the technopolis sectors. Although higher education was previously noted as excluded from study, their volunteers were at work among our population, and ignoring this circumstance seemed impractical. Instead, it was determined to ask about recruiting from higher education as a way to pursue a more complete picture of STEM professional volunteers in the setting under study.

Phase 1 identified new recruiting practices that had not been previously considered. Variations of recruiting of parents and former students were mentioned, as were specific circumstances where parents proactively volunteer, and where volunteers simply arrive via word-of-mouth. It was determined to add recruiting of parents and recruiting of former students to the Phase 2 survey. Recruiting of former students was limited in the operational definition offered in the survey to those who are now STEM professionals.

Word-of-mouth volunteer arrivals, of parents or in general, does not reflect a proactive practice of educators, and was not carried forward as a practice. However, a general question was included in Phase 2 about these potential events. Knowing whether volunteers arrive without educator effort is knowledge relevant to the research questions of this study.

Finally, from Phase 1 results, I noted other shortcomings that were easily addressed. Company sizes were not operationally defined. It was determined to use number of employees in definitions. Also, no opportunity was provided to report general assistance from volunteers outside the types identified. A general assistance question was added.

4.2.5 Refined List and Operational Definitions

Phase 1 results were synthesized into the list of practices from the literature review. Significant additions were made to the minimal recruiting practice list derived from the literature. Adjustments were made to the volunteer deployment practice list. Table 4.5 and Table 4.6 lists the practices and operational definitions carried forward to Phase 2.

Table 4.5

Recruiting Practices and Definitions Carried Forward to Phase 2

Practice Definition
1. Recruit from large companies (1000+ employees).
2. Recruit from medium companies (100-999 employees).
3. Recruit from small-but-established companies (1-100 employees).
4. Recruit from startups.
5. Recruit from government employers (includes military).
6. Recruit from institutes of higher education (colleges, universities).
7. Recruit from non-profits.
8. Recruit through your host organization. (For example, do you rely on local or national organizations to find your volunteers? For those in CyberPatriot or FIRST, this refers to your local organizations.)
9. Recruit using your network/personal contacts.
10. Recruit parents of your students who are STEM professionals.
11. Recruit former students who are now STEM professionals.

Table 4.6

Deployment Practices and Definitions Carried Forward to Phase 2

Practice Definitions
1. Speak to students about careers.
2. Mentor students (consistent volunteering, over time, intent to impact outcomes).
3. Help students with projects (in formal or informal settings).
4. Directly teach content to students (this refers to volunteers teaching subject matter content, including cases where they are teaching content beyond your current level of knowledge).
5. Host field trips.
6. General assistance (be present, answer questions, help where needed).
7. Help you (the teacher) understand workplace application of content.
8. Develop curriculum / suggest curriculum content.
9. Deliver and/or host PD (professional development).
10. Secure resources (equipment, money) for program.
11. Equipment setup, configure, maintain.

4.3 Phase 2a, Quantitative, Educator Survey

A count of *N*=24 participants completed the Educator Survey assessing the importance of educator recruiting and volunteer deployment practices. For recruiting practices, results included unidimensional scales for the subgroups *industry organization size*, *organization sectors*, and *local resources*, generated through pairwise comparison. Results also included a Likert scale ranking of all eleven recruiting practices explored. For volunteer deployment practices, results included unidimensional scales for the subgroups *working directly with students* and *supporting teachers*, generated through pairwise comparison, and a Likert scale ranking of all eleven deployment practices explored. General demographics and information of interest based on Phase 1 were also collected. The previous chapter on Research Methods provided an explanation and rationale for the pairwise comparison subgroups, and it also provided an explanation of adaptations made during study execution.

4.3.1 Demographics

Among the 24 participants in Phase 2, 18 were male, and 6 were female. A count of 19 participants were between the ages of 36 and 55, with an estimated average age across all 24 participants of 45 years, calculated assuming that each participant's age was in the middle of their chosen age range. A count of 20 participants were coaches in the San Antonio-area CyberPatriot program, and the remaining 4 participants were coaches in FIRST-Alamo Region. Generally speaking, participants were evenly distributed among schools of different sizes. Six participants were from rural schools, and the remainder closely split between urban schools (eight) and suburban schools (ten). Among the participants, 46% worked in Title I schools.

Demographics are summarized visually in Figure 4.1 and Figure 4.2.

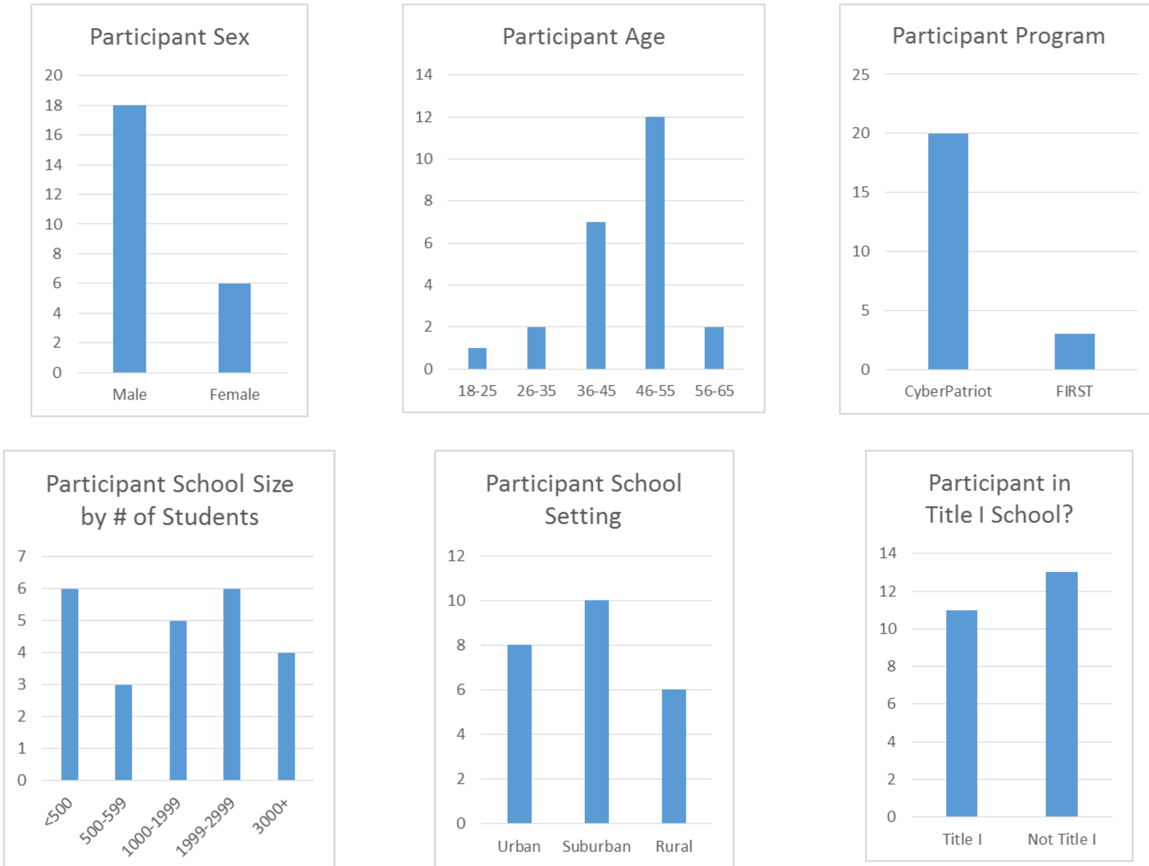


Figure 4.1. Phase 2 participant demographics.

4.3.2 Recruiting Data

Table 4.7 contains the results of pairwise comparison analysis using the RANKO and TRICIR tools provided by Dunn-Rankin et al. (2004). Each unidimensional scale shows the relative importance of the practices within a recruiting subgroup, with higher scores indicating more highly rated items. Circular triad analysis results are described, and significantly different pairs are indicated. For brevity, the most compact approach to describing significance specific to each case is adopted (e.g., *all significant except*, or *none significant except*). It is noted that no participant had more than one CT, and no cause was seen to discard participant responses or psychological objects (practices) based on pairwise comparison results.

Table 4.7

Recruiting Practices, Pairwise Comparison Results

<table>
<tr><th>Subgroup / Importance of Practices</th><th>Circular Triads (CTs) /
Pairs Significantly Different</th></tr>
<tr><td rowspan="2">Industry Organization Size<pre>
0   10   20   30   40   50   60   70   80   90   100

+----+----+--X-+----+-X--+--X-+----+--X-+----+----+
          Startup   Large Medium   Small
           (26)   (43)   (56)   (75)
</pre></td><td>4 participants with 1 CT
Large and Medium, 4 CTs each
Small, 3 CTs
Startup, 1 CT</td></tr>
<tr><td>Medium-Large just short of p<.05
All other pairs, p<.001</td></tr>
<tr><td rowspan="2">Organization Sectors<pre>
0   10   20   30   40   50   60   70   80   90   100

+----+---X-----+----+----+--XX-+----X----+----+----+
   Non-profit(19)   Industry(56) Government(69)
                    Higher Ed(56)
</pre></td><td>1 participant with 1 CT
Industry, Higher Ed, Government, 1 CT each</td></tr>
<tr><td>Government-Industry, p<.05
Government-Higher Ed, p<.05
Industry-Non-profit, p<.001
Higher Ed-Non-profit, p<.001
Government-Non-profit, p<.001</td></tr>
<tr><td rowspan="2">Local Resources<pre>
0   10   20   30   40   50   60   70   80   90   100

+----+----+----+----+-X-XX---X+----+----+----+----+
           Program Host Net(49) Former students(57)
                   (44) Parents(50)
</pre></td><td>6 participants with 1 CT
Program Host, 6 CTs
Network, 5 CTs
Former Students, 4 CTs
Parents, 3 CTs</td></tr>
<tr><td>Program Host-Former Students just short of p<.05
No significant differences</td></tr>
</table>

Table 4.8 contains means and standard deviations from responses to the Likert scale ratings of the importance of recruiting practices. Available ratings were from 1 to 10, with 10 being the most important. Additional columns show which pairwise comparison subgroup each practice was in. These columns help the reader see how the subgroups distributed across the spectrum of Likert ratings. Unlike in the pairwise comparison, a composite industry rating was

not requested, as one can see participant beliefs about industry recruiting through the individual ratings for startup, small, medium and large companies.

Table 4.8

Recruiting Practices, Mean Likert Scale Ratings

Industry	Sectors	Local	Recruiting Practice	Mean Rating	Std Dev
		X	Former students	8.25	1.94
		X	Parents	7.92	2.15
	X		Government	7.08	2.92
		X	Program Host	7.08	2.67
		X	Personal Network	6.88	3.15
X			Small companies	6.71	3.04
	X		Higher education	6.50	2.98
X			Large companies	6.38	2.58
X			Medium companies	6.29	2.88
	X		Non-profits	5.58	3.05
X			Startups	5.50	2.95

Upon noting how ratings appeared to differ between the groups–the ones created by necessity to support a manageable pairwise comparison in Phase 2–it was decided to perform a t-test-for-means analysis looking for differences between the groups. For the industry group, the average of the industry ratings was included equally alongside the ratings for recruiting with government, industry, and non-profit sectors. Recruiting using local resources was significantly higher than industry-oriented recruiting at $p<.05$ ($p=0.011$), with an effect size (Becker, 2000) of 0.298. Recruiting using local resources was significantly higher than sector-oriented recruiting at $p<.05$, with an effect size of 0.269. There was no significant difference between industry- and sector-oriented recruiting.

4.3.3 Recruiting Analysis

4.3.3.1 Industry Organization Size

Among different-sized industry organizations, participants expressed a clear preference for recruiting from small companies, defined as less than 100 employees. A relatively high variance in participant answers is noted. By far the least interesting target for volunteer recruiting was startup companies. Results for medium and large companies were close, and appeared in different orders between the pairwise comparison and Likert results. It is concluded that there was no clear preference between medium and large companies.

While preferences were mostly clear among the different-sized organizations in pairwise comparison, they appeared largely at the bottom of the priority list when shown jointly with other recruiting practices. The differences between their Likert scale ratings appeared less pronounced. Consideration within the full recruiting group indicated that recruiting directly from industry was not, on the whole, highly valued.

4.3.3.2 Sectors

Recruiting from government organizations, which included active duty military volunteers, was strongly viewed as the most important recruiting target. Recruiting from non-profit organizations was clearly viewed as the least important. While Likert scores give a small advantage to recruiting from higher education versus industry, pairwise comparison results were identical, and no difference can be argued between higher education and industry.

4.3.3.3 Local Resources

Considered separately, differences in importance between the ways educators recruit using local resources is perceivable, but less clear. Recruiting former students received the highest importance, and recruiting parents who are STEM professionals second, though less clear from pairwise comparison results. Using one's personal network, and recruiting through the program host, were the least important, but the pairwise comparison analysis did not identify a statistically significant difference between these practices and the higher ranked practices. A higher number of CTs is also noted, and might be attributable to the less clear differences among the items in the minds of participants.

When considered within the full recruiting group, recruiting using local resources was scored highly. All four recruiting practices were among the top five practices in Likert rating scores. Recruiting former students and recruiting parents were the highest ranked practices.

4.3.3.4 Overall

Educators rated as most important recruiting volunteers using local resources. Recruiting from government was highly rated, with the distinction of being the only recruiting practice more highly rated than any local resource recruiting practice. Recruiting from industry was generally rated low, with the possible exception of recruiting from small companies. Recruiting from non-profits and startups was rated as low in importance.

4.3.4 Volunteer Deployment Data

Table 4.9 contains the results of pairwise comparisons performed using the RANKO and TRICIR tools for how educators deploy STEM professional volunteers. Each unidimensional scale shows the relative importance of the practices within one volunteer deployment subgroup, with higher scores indicating more highly rated practices. The table also lists results from circular triad analysis, and significantly different pairs are indicated.

Table 4.9

Volunteer Deployment Practices, Pairwise Comparison Results

<table>
<tr><th>Subgroup / Importance of Practices</th><th>Circular Triads (CTs) /
Pairs Significantly Different</th></tr>
<tr><td rowspan="2">Working Directly with Students (N=22)

0 10 20 30 40 50 60 70 80 90 100

+----+----+--X-+--X-+---X+X---X+----+----+X---+----+
General(25) Direct Instruction(52)
Field Trip Speak Projects Mentor
(35) (48) (58) (83)</td><td>• Two participants w/6 CTs discarded
• List of remaining participant CTs:
3, 2, 2, 2; all others 0.
• Mentor, 4 CTs
• Projects, 1 CT
• Direct(ly) (teach content), 7 CTs
• Speak (to students about careers), 5 CTs
• Field Trip, 5 CTs
• General, 5 CTs</td></tr>
<tr><td>• Not sig.: Projects-Direct(ly teach content)
• Not sig.: Projects-Speak
• Not sig.: Speak (careers)-Direct(ly teach)
• Not sig.: Field Trip-General
• All other pairs significant, p<.001</td></tr>
<tr><td rowspan="2">Supporting Teachers

0 10 20 30 40 50 60 70 80 90 100

+----+----+----+----+X-X-+XX--X----+----+----+----+
Equipment(41) Application(54)
PD Resrc Curriculum
(45) (51) (59)</td><td>• 2 participants with 2 CTs
• 9 participants with 1 CT
• 8 CTs in all practices, except
• 7 CTs in Equipment (setup, config, main.)</td></tr>
<tr><td>• Curriculum-Prof Dev, p<.001
• Curriculum-Equipment, p<.001
• Application-Equipment, p<.001
• All other pairs not significant</td></tr>
</table>

Table 4.10 contains means and standard deviations from responses to the Likert scale ratings of recruiting practices. Available ratings were from 1 to 10, with 10 being the most important. Additional columns show the practices' pairwise comparison subgroup. These columns help the reader see how the subgroups distributed across the spectrum of ratings.

Table 4.10

Volunteer Deployment Practices, Mean Likert Scale Ratings

Direct to Students	Support Teachers	Volunteer Deployment Practice	Mean Rating	Std Dev
X		Mentor students	9.21	1.14
X		Speak to students about careers	8.38	1.69
	X	Help you understand workplace application	7.42	2.65
X		Help students with projects	7.21	2.50
X		Directly teach content to students	7.08	2.30
	X	Secure resources	7.04	2.73
X		General assistance	6.42	2.89
	X	Develop curriculum / suggest content	6.42	2.57
	X	Equipment setup, configure, maintain	5.79	3.26
	X	Deliver and/or host PD	5.71	2.94
X		Host field trips	5.13	3.00

In addition, a t-test-for-means was performed looking for differences between the two groups. Two measures were created for working directly with students, with one measure omitting field trips from the average calculation, with the rationale that field trips serve teachers and students, and are the only activity requiring taking students outside their school. The two groups were significantly different using either working-directly-with-students measure: $p<.05$ when including field trips, with an effect size of 0.214 (Becker, 2000), and $p<.01$ ($p=.002$) when omitting field trips, with an effect size of 0.322.

4.3.5 Volunteer Deployment Analysis

4.3.5.1 Working Directly with Students

Educators indicated clear preference for mentorship as the most important deployment of STEM professional volunteers, confirmed by both pairwise comparison and Likert scale results. Speaking to students about careers was well rated overall, though clearly higher in Likert results. Helping students with projects was well rated overall. Volunteers hosting field trips was the least important practice. Volunteers providing general assistance was low-rated, being very low in pairwise comparison, and low in the Likert rating. Speaking to students about careers, directly instructing students in content, and helping students with projects clustered in the middle of educators' preferences.

Notable was the relatively high numbers of circular triads. Two respondents had a very high number of CTs. Their responses were discarded. The *directly teach content to students* practice was included in 7 CTs. The practices of speaking to students about careers, field trips, and general assistance contained 5 CTs each. With these observations made, it was still the case that, compared to theoretically random answers, TRICIR reported only a 5.55% chance that answers about direct instruction were not random, and less than 5% for the remaining practices. I concluded that clarity in the minds of participants was sufficient.

Nevertheless, opportunities exist for sharpening of definitions, and perhaps better description of distinctions between practices. For example, directly teaching content to students might be interpreted by some as happening during mentorship, while others might view direct teaching as a distinct activity or tied to core academic content. Likewise, speaking to students about careers, which clearly happens during mentorship, also occurs as a distinct activity outside mentorship; interpretations may have varied between participants regarding whether speaking to students about careers included those occurrences during mentorship.

4.3.5.2 Supporting Teachers

Overall, less clarity is observed regarding how educators valued behind-the-scenes support for teachers. Helping educators understand workplace application was rated high in general in Likert results, but just above mid-range in its group in pairwise comparison results. Helping with curriculum was rated high among its group in pairwise comparison, but lower among its group in Likert results. Less valued, according to Likert and pairwise comparison results, was helping with equipment setup, configuration and maintenance, and delivering/hosting professional development.

Once again, circular triads were relatively high, and exclusion of the possibility of non-random results was only measured at approximately 13% for individual practices. However, the occurrence of CTs was spread more evenly among participants (after the discarding of two responses) and more evenly among the practices. Given the relatively tight clustering of ratings, one might conclude that more CTs simply reflected the less clear decisions that had to be made by survey participants. It is also noted that, for both deployment pairwise groups, even after creating subgroups, the number of practices exceeds the limit given by Dunn-Rankin et al. (2004) given the number of educators participating in the survey, to achieve reliable results.

4.3.5.3 Practices with High Variance

Significant variance is noted in two low-rated items. *Equipment setup, configure,* *maintain* showed high variance, as did the practice of field trips. One might speculate that such practices vary significantly based on local circumstances.

4.3.5.4 Overall

Educators showed a clear preference for giving volunteers direct access to students for mentoring, sharing information about real-world experiences in their careers, and sharing information about career opportunities. Educators were interested in receiving behind-the-scenes support from volunteers, but not to the extent they desired volunteers to interact directly with students. Equipment setup, configuration and maintenance, and delivery of professional development, were given relatively low importance. It is noted that among the 24 participants, 7 participants rated against the trend, giving higher ratings to behind-the-scenes teacher support than to working directly with students.

4.3.6 General Questions / Phase 1 Follow-Up

Selected issues identified in Phase 1, while not warranting the addition of practices for study, still raised issues which affect the overall characterization of STEM professional volunteers in the programs under study. Phase 1 participants made comments that suggested some recruiting happens by word-of-mouth, with little or no effort required by an educator to proactively find volunteers. This led me to realize that the current study assumes educators want STEM professional volunteers. In light of these concerns, questions were added to gain relevant insights.

Participant responses made it clear that they want volunteers, and that word-of-mouth among parents and others does not address volunteer needs. Zero participants indicated that word-of-mouth yields *many* volunteers. Collectively, 20 of 24 participants indicated they receive a few or no volunteers by word-of-mouth. Meanwhile, two participants indicated they have enough volunteers, while 22 participants do not have enough volunteers. All participants indicated that they want STEM professional volunteers. Figure 4.2 shows graphs of the three questions used to solicit input on these topics.

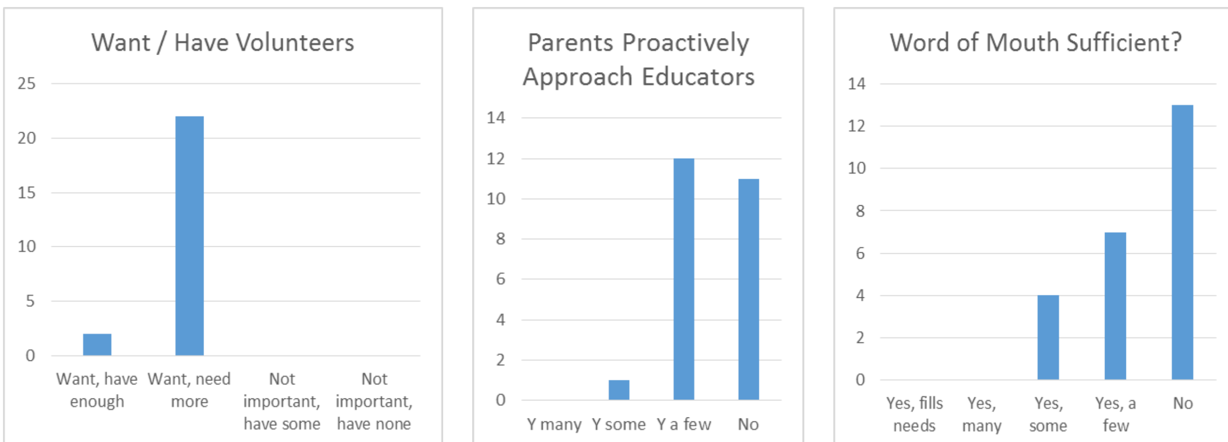


Figure 4.2. Graphs for word-of-mouth and desire for volunteers.

4.4 Phase 2b, Quantitative, CLES Instrument

A count of N = 23 participants completed the CLES instrument. The instrument measured the pedagogy in practice for the programs under study. CLES scale reliability was measured, and correlations were sought between educator practices and CLES scale measurements.

4.4.1 Scale Reliability

SPSS was used to assess the reliability of the CLES scales for the current data set. All reliability measurements were at or above *very good* as defined by DeVellis (2012). Table 4.11 lists the value of Cronbach's alpha for each scale.

Table 4.11

CLES Scale Reliability

CLES scale	Colloquial name as seen on survey	Cronbach's alpha
Personal relevance	Learning About the World	0.808
Critical voice	Learning to Speak Out	0.873
Shared control	Learning to Learn	0.918
Student negotiation	Learning to Communicate	0.936

4.4.2 Presence of Constructivist Practices

Scale score averages were calculated and are illustrated in Figure 4.3. Higher scores indicate greater presence of constructivist practices. The standard deviation is shown to convey the agreement among survey participants.

4.4.3 Educator Practice to CLES Scale Correlations

SPSS was used to calculate Pearson's correlation for all combinations of (1) educator practices, versus (2) CLES scale averages. Correlations were also calculated between (1) educator practices, and (2) demographics and general information items. Table 4.12 lists the significant correlations at $p<.01$, and related correlations adding support for the same practices.

It was noted that selected additional practices exhibited relatively high, if not quite significant, correlations across multiple CLES scales. These observations are listed in Table 4.13. All scales are listed for each educator practice, including those without good correlation.

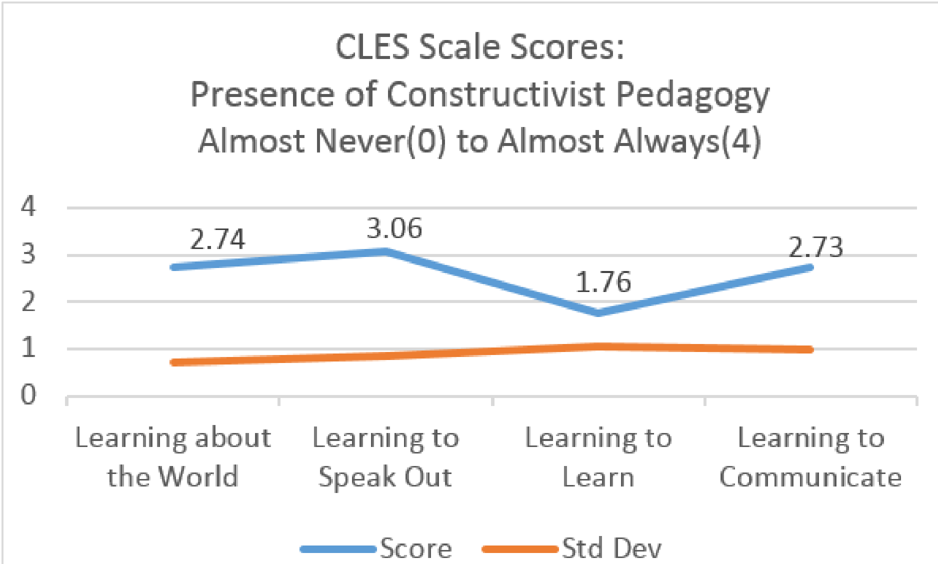


Figure 4.3. CLES scale scores.

Table 4.12

Practices to CLES, Correlations of p<.01, with Related Correlations

Practice	CLES scale	Pearson's correlation	Sig.	Notes
Recruit parents	Learning about the World	0.529	p<.01	
Parents proactively volunteer	Learning about the World	0.508	p<.05	p=.013
Mentor students	Learning to Communicate	0.584	p<.01	
Mentor students	Learning to Speak Out	0.431	p<.05	
School size	Learning to Speak Out	-0.588	p<.01	

Table 4.13

Near-Correlations of Practices to CLES Scales

	Significance (shaded items p<=.11)			
Practices	Learning about the World	Learning to Speak Out	Learning to Learn	Learning to Communicate
Recruit from government	0.59	0.09	0.10	0.05
Recruit through program host	0.28	0.11	0.26	0.02
Work with students on projects	0.16	0.26	0.07	0.06
Recruit former students	0.05	0.10	0.92	0.06

Finally, it was observed that practices rated highly by participants were more likely to appear in significant or near-significant correlations with one or more CLES scales. This observation is illustrated in Table 4.14, with educator practices listed in two categories. The first category contains practices with at least one correlation of significance $p <= .11$ or less, and the second category lists those practices with no correlation of $p <= .11$ or less. There is no practice whose correlation results, viewed through the $p <= .11$ lens, are in obvious conflict with its rating by participants. The practices *recruit through program host*, *recruit from small companies*, and *recruit through personal network* received moderate ratings and or a mixed pairwise-comparison-versus-Likert result, and one might express mild surprise at their placement in Table 4.14. For all other practices, those rated well appeared in $p <= .11$ correlations, and those not rated well did not appear in $p <= .11$ correlations. It is noted as background that correlations were originally examined at $p < .01$, .05, .10, and .20. I observed the pattern of higher-rated practices appearing in stronger correlations. The cutoff of $p < .11$ was chosen to include one correlation just outside $p < .10$, believing it well-reflected the emerging narrative. In addition to correlations for practices, correlations for demographics and general information items are listed in the table.

4.4.3.1 CLES Scale Reliability

Phase 2b's design was dependent on the reliability of the CLES scales in the current population, and specifically within the context of their designated use in this study, where the CLES instrument was completed by educators versus students. The scales proved highly reliable, with all Cronbach alpha measurements at or above 0.800, and two alpha measurements above 0.900. CLES scale reliability supported proceeding per the study design.

Table 4.14

Categorization of Practices Based on p<=.11 Correlations

At least one p<=.11 correlation	No p<=.11 correlations
Recruit from government	Recruit large companies
Recruit through program host	Recruit medium companies
Recruit parents	Recruit small companies
Recruit former students	Recruit startups
Deploy: Speak to students about careers	Recruit from higher education
Deploy: Mentor students	Recruit from non-profits
Deploy: Help students with projects	Recruit using personal network
Deploy: Help you understand application	Deploy: Directly teach content to students
Parents proactively volunteer**	Deploy: Host field trips
School size* **	Deploy: General assistance to students
	Deploy: Help with curriculum
All correlations positive unless noted.	Deploy: Provide professional development
	Deploy: Help secure resources
**Negative correlation: Larger school*	Deploy: Equipment setup, config, maintain
size = less likely students speak out.	Word of mouth recruiting is sufficient
	Age
***Demographic or Phase 1 follow-up*	School type (urban, suburban, rural)
question, not a practice.	Title I school

4.4.3.2 Presence of Constructivist Pedagogy

CLES scale scores suggest that constructivist practices are often present in the programs under study. An exception is the enabling of students to influence the activities in their learning environment. One might ascribe this results to the relatively regimented outcomes required in CyberPatriot competitions, compared to programs more amenable to open-ended results.

4.4.3.3 Recruiting

Correlations were identified between recruiting practices and the pedagogy reported in the programs under study. Educators reporting that recruiting parents was important also generally reported that students learned about the real world in their program. Similarly, educators reporting that parents proactively volunteered also generally reported that students learn about the real world. Investigating why recruiting parents correlates to these constructivist behavior reports is identified as a prime topic for Phase 3.

Meanwhile, those educators who valued recruiting former students tended to report that students learned about the real world, spoke up out about their learning, and engaged in discourse with fellow students. These relationships warrant further investigation. Finally, educators valued recruiting from government organizations, including from the military. An obvious speculation relates to the large military presence in San Antonio and its associated cyber security footprint.

4.4.3.4 Volunteer Deployment

Mentoring students and working with students on projects showed the strongest relationships to the pedagogy reported in programs. Educators who valued mentoring generally reported that students learned to have discourse with fellow students, and that they learned to speak out about their learning. Educators who valued having volunteers work with students on projects reported their students engaged in discourse, influenced the methods of learning in the program setting, and to a less clear degree, learned about the real world. Gaining insights into why mentorship and projects correlated to reports of the presence of constructivist pedagogy is identified as a goal for Phase 3.

4.4.3.5 Other Observations

Two additional observations are noted. First, school size showed negative correlation to students learning to speak out about their learning. The larger the school, the less likely that educators would report students as learning to speak out. Second, it was noted how the practices appearing in correlations were also reported as important in pairwise comparisons and Likert responses. The search for correlations tended to highlight the same practices already surfaced as important. This was interpreted as a form of criterion validity for practice ratings, and likewise, it supported argument for legitimacy of the correlations.

4.5 Phase 3, Explanatory Qualitative, Semi-Structured Interview

4.5.1 Focus on CyberPatriot

It was previously noted that, to protect against study risks, participants were invited from FIRST-Alamo Region for Phase 2. With Phase 2 complete, it was noted that 83% of participants came from CyberPatriot. It was determined that Phase 3 should focus solely on CyberPatriot educators.

To confirm the validity of this approach, supplemental analysis was performed, comparing the Phase 2a ratings of FIRST educators to overall ratings. For recruiting practices, ratings from FIRST participants were uniformly higher across all practices. Analyzing rankings, high- and low-ranked practices were consistent between FIRST participants and the overall group, and items moderately ranked were bunched together by FIRST participants in a manner generally consistent with overall rankings. No differences of interest were noted.

For volunteer deployment practices, results were more nuanced. FIRST participants rated mentorship first and field trips last, as did the overall group. Professional development, and equipment setup, configuration and maintenance, were rated significantly lower by FIRST participants. However, neither of these items were highly rated overall, and no significance to the emerging narrative was noted.

The two most notable deployment observations were relatively higher ratings from FIRST participants for understanding workplace application, which was six positions higher at position three, and lower ratings for directly teaching content to students, which was ranked three positions lower at position five. I had observed that 7 of 24 participants rated behind-the-scenes support for educators higher than direct contact with students; of these, three showed the greatest difference. The similarity of these observations was noted, and I determined to better understand the minority viewpoint of those giving greater value to behind-the-scenes educator support, through Phase 3 interviews.

4.5.2 Participants and Interviews

A count of $N = 3$ CyberPatriot participants completed a semi-structured interview. The interview was conducted using a script customized to seek explanations for the results observed in Phase 2. There were four main sections in the script. First, highly rated recruiting practices were explored. Second, highly rated volunteer deployment practices were explored. Third, all recruiting and deployment ratings were shared with the participant, and reactions were invited, including for low-rated items. Last, correlations were shared, and reactions invited. Appendix F lists the full script.

The pseudonyms for the participants are Paul, Alberto, and Edward. These three participants were chosen because they fit profiles of providing high, medium, and low ratings. Paul teaches at a large public school in a fairly prosperous area transitioning from a rural to suburban setting. He was previously a career military officer, and in his current career, teaches core high school science courses and elective courses. He has been an educator for seven years. Alberto was also a career military officer. He very recently began a second career as a Junior ROTC educator. Within that assignment, he teaches science topics at a large and socioeconomically middle class public high school in an outer suburban area of the city experiencing rapid growth. Edward was a former information systems professional for a defense contractor. He has been a teacher for seven years, and teaches in a small military-base-associated school district in a central urban area, at a combined junior and senior high school campus. He teaches a variety of career and technical education courses, many based on or using IT technology tools.

4.5.3 Codes

Constant comparative coding (Saldaña, 2009) was performed to analyze results. The focus of coding was on explaining more deeply the quantitative results from Phase 2, consistent with Creswell and Plano Clark’s (2011) description of explanatory mixed methods research. Table 4.15 lists all codes that received a count of three or greater during coding. Appendix H lists all Phase 3 codes.

Table 4.15

Phase 3 Codes, Count of Three or Greater

Code	Count
Evidence of affordance	35
Accessibility is important	16
Mentoring is related to pedagogy	10
Direct contact with students is important	6
Teacher is not meant to be technical expert	6
Technical knowledge is important	5
Highly value parents with technical knowledge	5
The meaning of *project* was unclear	4
Teacher's role is as manager of learning	4
Parents have and effectively share real-world experience	4
Mentors must bring and share technical knowledge	4
Parents are especially motivated	3
Parents especially contribute to pedagogy	3
Mentors are role models for students	3

4.5.4 Categories

I and the second coder continued constant comparative coding to identify categories of codes. Per Saldaña (2009), codes are similar to essential facts, while categories begin to create a "skeleton" (p. 8, citing Charmaz, 2006) from those facts. Table 4.16 lists the categories identified, with counts of how many codes contributed to identifying the categories. The immediately following sections discuss the categories identified, generally in order of their prevalence, with order adjustments to support stream of thought between the categories.

4.5.4.1 Evidence of Affordance

In multiple Phase 3 codes, I and the coder recognized the presence of affordances. An affordance is an action made possible by the presence of a tool within a specific environment; for example, to a deer in the forest, a tree enables the action *hide,* or *receive shade* (Gibson, 1986; Hammond, 2010; Dalgarno & Lee, 2010). Affordances are understood to be present in teaching and learning, and they are wielded by educational professionals as they deem appropriate to achieve learning goals. In the comments of the Phase 3 interview participants, one can observe educators' thought processes at work when they described how they used the affordances made available by STEM professional volunteers. Educators considered mission, local setting, detailed goals, circumstantial facilitators, constraints, and their personal experience as educators. Educators frequently referred to the needs they had or specifically did not have; for example, they needed technical skills, or they desired the atmosphere created by mentors, or they needed to avoid large company bureaucracy.

Table 4.16

Phase 3 Categories

Code	Count
Evidence of affordance	20
Topic of regional priority	16
Direct contact with students	14
Educators consider rapport	10
Constructivist pedagogy	8
Role modeling as pedagogy	8
Accessibility	7
Technical knowledge	7
Career opportunities	6
Back-end support	5
21st century skills	3
Parents and pedagogy	3

In the verbiage of affordances, I am reminded of a fundamental principle adopted for this study. This study was conducted from the viewpoint of educators. The idea of affordances provides a useful construct for considering the perspective of educators.

4.5.4.2 Topic of Regional Priority

Many comments highlighted the value that accrued to educators as a result of the strong focus on cyber security in the region. Edward's affinity for using parents as volunteers derived from factors beyond parents' normal advantages, and to his particular population's strong skills in information technology and cyber security. The teachers themselves worked in the field in their first careers. The regional focus on cyber security is a direct reason that a program host exists with strong local training programs. Paul specifically referred to recruiting from government as a "target-rich environment." In a different but related twist, one educator noted how the exponential increase in the number of local CyberPatriot teams is becoming a constraint to finding volunteers, who when not naturally connected to specific schools, have a choice of which school to serve. Success in finding and supporting volunteers rests in significant ways on the strength of the cyber security economic cluster in the region.

4.5.4.3 Accessibility

As used here, accessibility refers to an educator's ability to easily access and use an affordance available for recruiting or volunteer deployment. All Phase 3 participants made direct comments about accessibility. Paul made an insightful comment when he first reviewed the mean scores for recruiting practices. The local recruiting practices were color-coded green.

He commented, “The green stuff is high just because it’s accessible.” To the same question, Edward replied “those are just the easiest ones.”

That sentiment was expressed repeatedly. Parents were noted as both accessible and as having a vested interest in the program via their children. Paul said, “The gold standard for me is a parent who is an IT professional,” a situation he encountered regularly in his CyberPatriot student population. Alberto said it is “easier to ask a parent to volunteer and help out rather than reaching out to complete strangers.” Edward’s situation was unusual in that many parents were cyber experts. Edward stated that working with parents was “less hoops to jump.” Alberto noted that familiarity helps teachers know who will work well with students; I interpreted familiarity as a form of accessibility.

Finally, accessibility was noted via comments on difficult-to-access volunteer affordances. Paul noted the bureaucracy in large companies as a barrier to engaging their staff, preferring to work with small companies. Edward stated that using volunteers to help with equipment setup, configuration and maintenance is difficult because volunteers lack physical or security access to computers. Edward also rated recruiting former students low, unlike most of his colleagues, because his former students follow their parents when they receive military orders—they are simply no longer around. Accessibility was a concern that cut across all the detailed needs which educators attempt to address with volunteers.

4.5.4.4 Constructivist Pedagogy

It was clear from interviews, and consistent with Phase 2b correlation results, that the presence of volunteers helped create a constructivist pedagogical environment. In addition, Phase 3 interviewees made comments suggesting that the particular environment created would be difficult to reproduce through other means. Two particular insights were: (1) how students viewed volunteer mentors less formally than they viewed the teacher, and (2) how the volunteers used that atmosphere to model real-world behaviors. Edward spoke about “the atmosphere that is created when the mentors are here.” Edward said that students “don’t see the mentors as teachers.” Paul said that the informal method of teaching naturally employed by the volunteers can be a better way for students to learn technical content. Paul described the atmosphere created by mentors as follows:

> They're not there to be a teacher, per se, and they tend to interact in a more casual, communicative way. The students don't see them as their teacher, and a lot of times they're pretty good at just asking questions… [students] have to have a dialogue back and forth and do that problem solving process as a team with the mentor working with them…

I noted the background of the educators themselves. Being second-career teachers who previously worked in the military or industry, they likely had greater innate awareness of the affordances available through professional volunteers. One can argue that educators with such backgrounds should be especially effective mediators for engaging STEM professional volunteers.

4.5.4.5 Direct Contact with Students

The importance of the pedagogical atmosphere seemed to be a factor in the higher ratings given to practices that put volunteers in direct contact with students. While discussing his relatively low scores for curriculum development, resource acquisition, and equipment setup, Alberto said he “thought of these things as kind of my responsibility.” (For completeness, it must be noted that Alberto had since encountered an opportunity, not yet realized, for interesting back-end support.) Edward stated clearly that his priority was to “maximize [volunteers’] exposure to students.”

4.5.4.6 Parents’ Special Contribution to Pedagogy

Still related to the topic of direct contact with students, but now specific to parent volunteers, educators perceived special pedagogical value in parents who could also serve as technical experts and mentors. Educators considered parents to be accessible, relative to other potential volunteers. Regarding pedagogy, many parents were active duty military, had traveled widely, and/or had gained substantial practical experience. Combined with their vested interest, and their familiarity with other students, parents, teachers, and school culture, educators perceived mentor-parents as especially effective when channeling their real-world knowledge to students.

4.5.4.7 Role Modeling as Pedagogy

Educators valued volunteers acting as role models. One example regards their recent former students. Educators found recently-graduated former students as highly effective influencers of current students. Paul noted, “Here's someone who, two years ago, was doing what you're doing, and now they're majoring in it at UTSA or wherever they might be. It just lets [current students] see the whole pipeline.” Alberto’s interest in former students was informed by his own experience as a young college student returning to talk to students at his high school.

Those recent students, many in college, did not all meet this study's definition of STEM *professional* volunteers; however, older STEM professionals were also viewed as effective role models. As previously noted, parents familiar with particular schools connected especially well with that school's students. Alberto noted the value volunteers provide when students see real examples of career opportunities associated with what they are learning. Alberto also made comments highlighting connections between role modeling and pedagogy. Among his three mentions of role models, two occurred while using mentorship in the same sentence, connecting the two practices. Alberto said:

> I think with the mentorship it goes beyond just teaching, it’s actually being a role model. It’s mentoring them. It’s teaching them about things beyond just what’s in the classroom. And as far as…the kids communicating…[and]…speaking out and being able to question why they’re learning things is because–because hopefully, by [seeing the volunteers] asking those kind of questions, then they’re able to really apply their knowledge to at least understand how that knowledge is important in the world.

Alberto’s comments highlighted how being a role model is another example of volunteers enabling affordances consistent with constructivist pedagogy. Teachers know that volunteers are role models. Having role models in contact with students leads to constructivist learning by students. Teachers make the decision to bring this capability to bear to meet learning goals for their students.

4.5.4.8 Educators Consider Rapport

Across multiple categories above, one can see how educators valued working with people they know. Educators valued working with former students, parents, and volunteers found locally. Asked to comment on their reasons, educators noted their higher ability to understand the strengths and weaknesses of such volunteers. Alberto stated, “Some people just don't necessarily work well with teenagers, and they may think they do.” He also stated that “[I want to know] that I can trust them with the teenagers, and for me it's just kind of that personal trust and knowledge of their skills, and how good they are in the subject matter…” Regarding parents, they noted the advantages of parents’ familiarity with the school and students. They noted these advantages when discussing technical knowledge, development of 21st century skills, career awareness, and sharing of information about local careers.

A category that encapsulates these observations is *rapport*. Jones, Warren and Robertson (2009) described the importance of rapport in teaching and learning. They described rapport as the feeling of “being ‘in sync’” (p. 271). They related rapport to familiarity, and noted that when rapport exists between teacher and student, benefits are seen within weeks of the start of teaching, benefits that increase student satisfaction and discourse. The thought processes of Phase 3 participants showed them considering rapport among the students, teachers and STEM professional volunteers working together in programs.

4.5.4.9 Technical, 21st Century, and Career Knowledge

Educators have specific knowledge in mind that they wish students to learn, and they see volunteers providing affordances to support that knowledge transfer. In particular, the ability of volunteers to bring technical knowledge as part of their volunteer role was fundamental to educators. Alberto referred to technical knowledge as “the first requirement…I wouldn’t bring someone on as a volunteer unless they are currently working in [the] field and have the technical background to actually teach the students.” The teachers recognized that volunteers with technical knowledge had significant impact on CyberPatriot competition performance. Edward referred to “a direct benefit—the kind that will help in the CyberPatriot program.”

The affordance perspective is also caught through the teachers’ comments about their own skills, or lack thereof, in the IT/cyber space, and the low priority they assigned to gaining those skills personally. That prioritization was not a lack of initiative, but rather an intentional decision by the teachers regarding their realistic and proper role versus that of volunteers. Paul stated it clearly when he said “I’m not in an IT professional, so I desperately need folks who are technically skilled, interested in the program and able to work with the kids to help motivate them to be those things that I cannot.” Alberto said, “I…depend a lot on the mentors and the volunteers to teach the students the content…I'm not trying to get to a point where I can teach this, because it's just way way beyond my knowledge.”

Educators wanted students to learn about careers and to learn 21st century skills. Educators valued students understanding content in real-world perspective, and they valued students being able to engage in discourse regarding that content. Educators valued students understanding real-world application and the pipelines that might lead to future education and careers. Educators desired this in both abstract terms—the *idea* of careers and the importance of college—and in very practical, local terms, where students gained awareness of local college opportunities and local internships, and where students gain social access to local networks that can guide the students to college and career opportunities.

4.5.4.10 Back-End Support

The back-end support category refers to help coming from outside the school on building resources, materials, processes, or volunteer capacity. Such help may come from volunteers, but it might also come from organizations or from CyberPatriot program staff. In this sense, it overlaps the Phase 2a survey category of behind-the-scenes support from volunteers, but it is not equivalent. Although not prevalent among Phase 3 participants, back-end support for local school programs was periodically seen in educators' thought processes. Alberto had the prospect of support from a specific industry sponsor, including help with curriculum, resources and equipment. Edward described support received from students from another school when preparing his new program, and he perceived challenges specific to small schools like his where he could benefit significant from outside help. This category highlights that back-end support is relevant, but also that back-end support is not always the domain of STEM professional volunteers.

4.5.4.11 Minority Report: Educators Prioritizing Behind-the-Scenes Support

Seven of 24 educators rated behind-the-scenes support more highly than volunteers' direct contact with students. Four of the seven educators provided ratings close to even for the two categories; three educators rated behind-the-scenes support significantly higher. Evidence of a different perspective also was seen in the comparison of FIRST participant's responses to overall responses. These facts were uncovered after Phase 3 execution had completed.

Through supplemental data collection via email queries, three responses were received that provided insights into the reasons these educators rated against the group consensus. The first educator's interpretation of the Phase 2a survey questions saw behind-the-scenes work as being co-performed by volunteers and students—a situation more consistent with the majority viewpoint. The second educator was a subject matter expert in the field, and therefore was self-sufficient on content. The third educator noted his desire for students to lead their own learning, including discovering subject matter content through their own efforts. The last two viewpoints clearly changed those two educators' calculations regarding which practices are most valued. It is noted for the reader that, despite the surface differences, these positions are consistent with the broader themes proposed in the upcoming section.

4.5.5 Themes

From the Phase 3 categories, I and the second coder arrived at five themes. The themes are practicality, pedagogy, knowledge and skills, rapport and climate. The themes are offered as the essential principles that drive the recruiting and deployment of STEM professional volunteers. The mapping of categories to themes is illustrated in Table 4.17.

Table 4.17

Categories and Themes

Mainly due to categories…	And consistent with categories…	Themes are…
Evidence of affordance Accessibility	Direct contact with students Educators consider rapport Topics of regional priority	Practicality
Direct contact with students Constructivist pedagogy Role model as pedagogy Parents and pedagogy	Topics of regional priority	Pedagogy
Technical knowledge Career opportunities 21st century skills	Direct contact with students	Knowledge and skills

Educators consider rapport Role modeling as pedagogy Parents and pedagogy	Career opportunities 21st century skills	Rapport
Topics of regional priority Accessibility Career opportunities	Evidence of affordance Back-end support Technical knowledge	Climate

4.5.5.1 Practicality

This theme encapsulates the goals educators are pursuing when engaging volunteers, their recognition and use of affordances to meet those goals, and educators' inclination to select the most accessible affordances available. Educators are professionals using tools to achieve goals. For the good of all, they will do so in the most practical manner possible. When they move out of the way so that volunteers can interact with students, or think about the best ways to build rapport, or choose topics embraced by the region where they live, they do so because it meets an important goal in a practical way.

4.5.5.2 Pedagogy

This theme encapsulates the embrace of constructivist pedagogy, the connections found between STEM professional volunteers and constructivism, the special ways parents can channel pedagogical approaches, and the place of mentors and role models in interacting directly with students. STEM professional volunteers enable constructivism in ways difficult to replicate through other means. Volunteers acting as role models represent a pedagogical approach to penetrating the minds of students.

4.5.5.3 Knowledge and Skills

Knowledge encapsulates technical facts, 21st century skills, and knowledge of careers. Using appropriate pedagogy, and in the most practical way possible, educators impart knowledge and skills to students. Volunteers offer affordances that are used by educators to impart knowledge and skills, often directly from the volunteers to the students.

4.5.5.4 Rapport

Rapport refers to the construct in educators' minds that drives them to create a student-teacher-volunteer team that is greater than the sum of its parts. When this construct operates, educators think not only of the immediate benefits of a volunteer, but also how that volunteer will fit and sustain in the program over time. One might speculate that educators seek a virtuous cycle, or at least a calm-and-steady cycle, among all program participants, because more learning happens when such an environment is present.

4.5.5.5 Climate

Climate is the macro-context in which the other themes operate and interact. Climate is built on a region's economic cluster. It is also created in part by the nature of the host programs and how local schools and educators are supported.

4.6 Summary

This chapter documented the results of data collection and provided the first-order analysis of those data. Phase 1's mostly qualitative results largely confirmed volunteer deployment practices emerging from the literature review as clear and complete, while shedding light on ways to supplement the limited information on recruiting practices identified from literature. Phase 2a's quantitative results indicated that recruiting former students, parents, and through locally available resources were more valued than recruiting from industry and other sectors. Phase 2a results also indicated that mentorship and projects were the most highly valued actions performed by volunteers, and that supporting teachers behind-the-scenes, while valued by some, generally was seen as standing in the way of volunteers spending more time directly with students. Phase 2b's correlation results suggested that recruiting of former students and parents related in some manner to the presence of constructivist practices, and that mentoring and helping students with projects also related to constructivist practices. Phase 3's semi-structured interviews and subsequent analysis led to the insight that, in volunteers, educators see affordances. When considering those affordances, educators consider practicality, pedagogy, the knowledge and skills being taught, and rapport. Educators do this within a climate set externally by a region's priority industry clusters and the support provided by host programs.

CHAPTER 5

RESULTS AND DISCUSSION

Chapter 5 offers answers to this study's research questions. The chapter also revisits themes from the literature that have held true during the study. A model is suggested that incorporates the emergent themes from the study. Implications for practice are provided. The reader is reminded of the limitations of the current study, and potential areas for future research are recommended.

5.1 Research Questions: Answers and Discussion

5.1.1 Most Important Recruiting Practices

Research Question 1 asked: *Which practices used to recruit STEM professional volunteers are most important to educators?* Phase 1 of the current study identified former students and parents as potential targets for recruiting that had not been considered based on the literature review. Phase 2 strongly indicated that educators see recruiting of former students and of parents as the most important recruiting practices. Table 5.1 includes a listing of the most- and least-valued recruiting practices.

I acknowledge that, based on interview results, it is not clear that the former students who were in the minds of participants were always former students who are now STEM professionals, despite a definition to the contrary provided to participants in the Phase 2a survey. Nevertheless, participants' reasons for prioritizing former students adds to the narrative emerging from the study. For this reason, the prioritization of this recruiting practice is embraced.

Beyond these two practices, it was also clear that recruiting through what I labeled *local resources* is more highly valued than recruiting from industry. Recruiting through local resources was also more highly valued than recruiting from the sectors of industry, higher education and non-profits. Only recruiting from government rivaled local resource ratings, and as one Phase 3 participant noted, for him "government is almost local," reflecting the strong connection between the government cyber security community and the cyber security education community within the primary population of this study.

5.1.2 Most Important Volunteer Deployment Practices

Research Question 2 asked: *Which deployments of STEM professional volunteers are most important to educators?* Educators most highly valued volunteers deployed in direct contact with students. Table 5.1 includes a listing of the most- and least-valued deployments.

Table 5.1

Most-valued and Least-valued Practices

	Most Valued	Least Valued
Recruiting	Recruiting former students Recruiting parents Category: Local resources	Recruiting from non-profits Recruiting from startups
Volunteer Deployment	Mentor students Speak to students about careers Help teacher understand workplace application Category: Direct to Students	Host field trips Deliver and/or host PD Equipment setup, configure, maintain General assistance

Direct contact with students was valued for mentorship, for sharing real-world and career experience, for helping students understand career opportunities and how to pursue them, and for guiding students through projects. Interviews with CyberPatriot coaches made it clear that direct contact was seen as improving student competition performance. Of the top five practices, four involved volunteers in direct contact with students. The two practices most highly rated were mentorship and speaking to students about careers.

Supporting educators behind the scenes was clearly less important, but still relevant. Helping educators understand workplace application, and providing support for developing curriculum, received the strongest support among behind-the-scenes practices. Securing resources was viewed as somewhat important. Equipment setup appeared less relevant in an environment where students, teachers and school technical staff are capable of performing setup, and where giving physical and electronic access to volunteers is not always straightforward. Delivering and/or hosting professional development was mostly viewed as taking away from volunteers' time with students. Field trips were valued by a few educators, but the complexity of administration and logistics are likely causes of a low rating.

5.1.3 Relating Practices to Constructivist Pedagogy

Research Question 3 asked: *What relationships exist between: (1) educators' practices for recruiting and deploying STEM professional volunteers, and (2) the constructivist pedagogical practices present in the programs under study?* Correlation results indicated there are a number of relationships. Table 5.2 lists the most significant correlation results.

Mentoring, recruiting parents, and recruiting former students appeared most strongly in correlations. Mentoring students was correlated with reports of students learning to communicate and learning to speak out about (comment on, critique) their learning experience. Recruiting parents and recruiting former students were correlated with reports of students learning about the real world, and were somewhat correlated to students learning to communicate, and also to students speaking out about their learning experience. Phase 3 interview results suggested that STEM professional volunteers enable constructivist-related affordances not easily made accessible through other means.

Table 5.2

Practices Correlating to Presence of Constructivist Pedagogy

Practice	Correlated to
Mentor students	Learning to Communicate, Learning to Speak Out
Recruit parents and Recruit former students	Learning about the World; near-correlations to Learning to Communicate, Learning to Speak Out
Multiple near-correlations with: • Recruit from government • Work with students on projects	

Highly-rated practices generally appeared in correlation results, and low-rated practices did not appear in correlation results. I interpreted this result as having two positive implications. First, it served as a type of internal criterion validity in the study. Criterion validity exists when independently-determined measures targeting the same constructs lead to similar results. Clearly, the measures are not fully independent; nevertheless, participants had no obligation to highly rate constructivist practices at the same time they highly rated their preferred recruiting and volunteer deployment practices. Second, the data are interpreted as suggesting that when highly-rated volunteer practices are in place, constructivist practices are stronger. Future research might seek latent variables and/or causal relationships. Prior to that step, this research might be repeated with constructivist practice measures coming directly from students.

5.1.4 Why STEM Educators Seek Relationships with STEM Professional Volunteers

Research Question 4 asked: *Why do STEM educators pursue relationships with STEM professional volunteers?* No specific phase of the study targeted this specific question; rather, all phases contributed to understanding the motivations of educators, and the answers offered are necessarily an interpretation of the data offered here. Four overlapping reasons are provided.

5.1.4.1 Volunteers Bring Knowledge and Skills Difficult to Access Elsewhere

Educators readily noted their shortcomings in the subject matter being taught in the programs under study. The subject matter included the direct knowledge and skills professional volunteers bring in the field, and also the contextual (real-world) knowledge volunteers offer. As professionals, educators look for the most efficient ways to achieve their goals. Professional volunteers must represent an efficient way to bring the knowledge and skills to students. It must be noted that at least one educator did possess good subject matter knowledge. That educator is likely representative of a minority. As one would expect, that educator found less value in volunteer knowledge and skills; still, the narrative is advanced that each educator uses the affordances made available as best fits their judgment and needs in local context.

5.1.4.2 Volunteers Positively Impact Student Competition Performance

This reason is quite straightforward. It is a natural implication of volunteers bringing knowledge and skills into programs. When volunteers do so, they positively impact competition performance, which is a high-profile measure of educator and student success.

5.1.4.3 Volunteers Complement the Self-Perceived Role of Educators

Not only did most educators not know the core knowledge and skills in question, but most also believed they did not need to know, and they did not make learning the knowledge and skills a priority for themselves. In their self-perception, their role was to manage, organize, resource, and professionally weave elements together to advance student learning. Volunteers used STEM professional volunteers as one of their tools to achieve their goals.

5.1.4.4 Volunteers Provide Affordances Not Easily Replicated

Knowledge, skills, and contextual knowledge, when delivered through an adult not in a position of authority over students, opened affordances not commonly available to educators. Volunteers were able to interact with students as near-peers, conducting discourse with students, sharing in inquiry, thinking critically about alternative solutions, thinking about how to learn and how to best apply knowledge in new and dynamic situations, and sharing their local knowledge of college and careers with students. The educators gained access to these affordances in return for the energy required to locate volunteers, administer their presence, and incorporate their presence. One must assume that educators participating in these practices find them to be a worthwhile return on the investment, and that they know how to bring the affordances to bear to achieve important results.

5.2 Discussion

5.2.1 Interpreting the Study in Context

The current study was executed within very specific populations. The educators who chose to participate were atypical of a random sample of secondary educators, or even of secondary STEM educators. For example, most of the educators were male; many were second-career teachers whose first careers were as military and/or STEM professionals; and many educators taught elective and/or Career and Technical Education (CTE) classes versus required academic classes. Most of the participants were part of the CyberPatriot program, and all received local training. These educators were focused on interactions with their own students and student teams, versus thinking about the kind of volunteer contingents needed to deliver large competition events of the type often encountered in the literature review. The reader should consider these characteristics when interpreting the study.

5.2.2 Consistency with Literature

I believe study outcomes have been consistent with the literature in three notable ways. First, I found that the narrative of educators as essential stakeholders when introducing new teaching and learning approaches is strongly reflected in the current study. Second, technopolis research has held true, as the impact of the local cyber security industry cluster clearly made itself felt in support of volunteer efforts in secondary education. Third, the use of the Gamse et al. (2014) research agenda as a platform has been appropriate, and a contribution has been made to that proposed research agenda.

The narrative that emerges from Cuban (1986, 2001), Ertmer et al. (2012), Hall and Hord (1987), Mishra and Koehler (2006), and Jones and Warren (2013) is that teachers are professionals who navigate their settings to achieve job requirements using available techniques and tools, and their concerns must be strongly considered when introducing new techniques and tools. One can readily observe in the Phase 3 interviews how educators' thinking is consistent with the literature's narrative. Educators had clear goals in mind regarding knowledge, skills and contextual knowledge. They considered the cost and made conclusions about where STEM professional volunteers bring the most impact in a manner practical for the educators to access. The Phase 3 themes of knowledge and skills, practicality, pedagogy and rapport are important elements of this narrative.

Regarding the technopolis model, one can see the impact of the San Antonio-area cyber security cluster on the cyber security education happening through CyberPatriot. A telling comment from Edward during Phase 3 interviews was that "government is almost local for me," illustrating how closely government employees and educators are to one another in the CyberPatriot program. The Phase 3 educators' prior careers were in the military and/or cyber security clusters. Smilor et al. (1989), Gibson et al. (1992) and Gibson and Butler (2013) argued that regions gain competitive advantage in economic development when their sectors work in collaboration. This attribute appears present in the region.

Finally, I argue that a meaningful contribution has been made to the Gamse et al. (2014) *STEM Corps* research agenda. Gamse et al.'s Research Agenda Item 1 was to "articulate the focus and scope of practices" (p. 18) of STEM professional volunteers in K-12 education. Their Agenda Item 1a was identification of common elements across roles and programs. The current study has more deeply studied educator practices in a local setting, building on a broad review of the literature. Gamse et al.'s Agenda Item 1b called for defining practices in ways that discriminate from other practices. This work has (1) been advanced, with (2) current study shortcomings identified, for example, in the importance of distinguishing projects from mentorship. Gamse et al.'s Agenda Item 2 called for models to be developed, and Item 3 called for empirical research. Empirical research has been conducted within the mixed methods design of the current study; surveys have been developed that could advance to become instruments; and a model is shared below regarding the mindset of educators as they deploy STEM professional volunteers.

5.3 Themes and Model: Educators and STEM Professional Volunteers

In the final analysis, I continue to embrace the importance of seeing the use of STEM professional volunteers through the eyes of educators. Furthermore, through the results of Phase 3, I see the theory of affordances at work. J. J. Gibson (1986) wrote how he created the term *affordance* to describe "something that refers to both the environment and the animal in a way that no existing term does" (Gibson, 1986, p. 127; cited in Hammond, 2010, p. 205). Dalgarno and Lee (2010) described an affordance in simple terms as "an action made possible by the availability of [a] tool" (p. 12). In the current study, STEM professional volunteers are the tool, the program under study is the environment (ecology), and the educator wields the tool within the environment, for a purpose they choose, and toward an outcome they judge important. When wielding the tool, educators consider questions consistent with the emergent themes of this study: knowledge and skills, pedagogy, practicality, and rapport. The emergent theme of climate surrounds the immediate local setting. Figure 5.1 illustrates the main ideas of the proposed model.

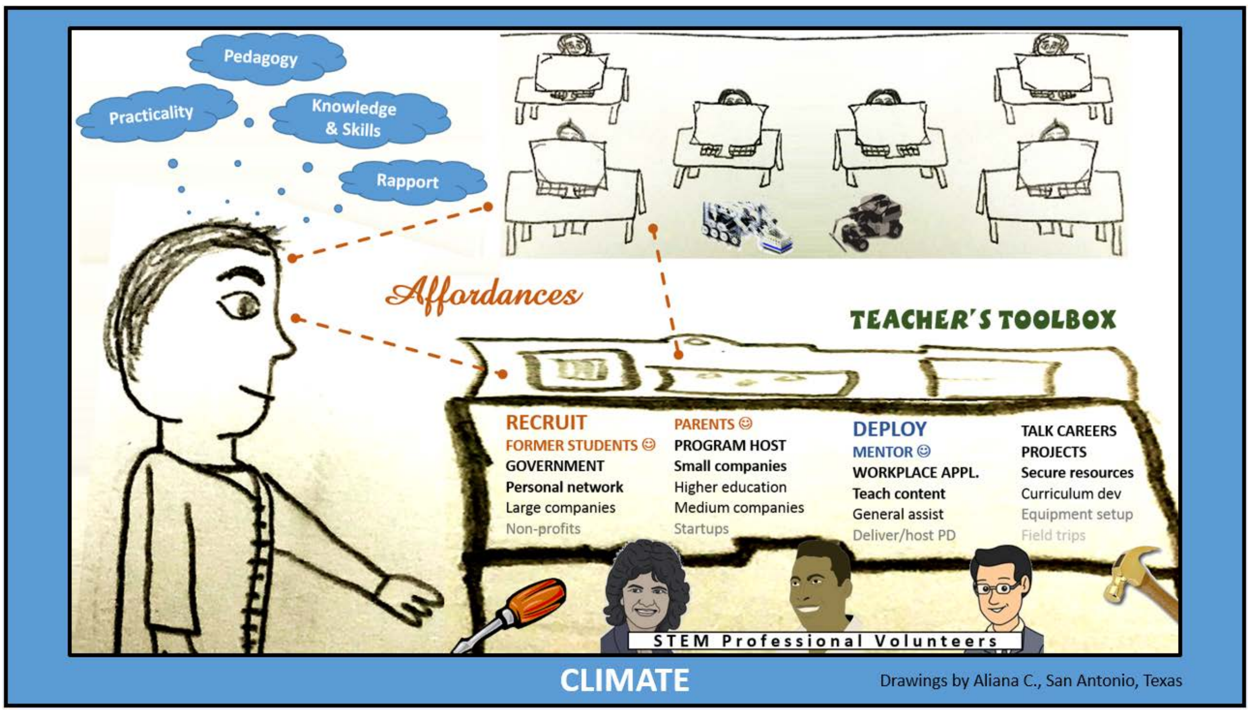


Figure 5.1. Proposed model: The educator's view of STEM professional volunteers.

5.3.1 Implications for Practice

Table 5.3 lists a number of implications for practice that can be derived from study results. Educators who are not doing so already should consider, when their setting is amenable, recruiting parent-professionals and former students as volunteers. Programs should provide robust tools to educators to help them recruit from their local resources, as such volunteers are more readily placed in the most appropriate role when educators know them well; also the likelihood of rapport developing among student and adult participants increases when volunteers are known. Programs should also recruit volunteers who bring important technical knowledge, skills, and context knowledge. The recruiting focus should be on volunteers who have the knowledge, skills and aptitude to mentor students and/or lead students through projects (notwithstanding the needs of volunteers for large events, a need that did not emerge given the scope of the current study). Programs should identify which local industry clusters can bring momentum to volunteer recruitment; when new programs are formed, their mission and goals might be aligned or even aimed directly at industry clusters most important in the region.

Table 5.3

Study Implications for Practice

Implication	Recruit	Deploy
Recruit parent-professionals.	X	
Recruit former students.	X	
Provide tools and support for educators to recruit local to their setting.	X	
Recruit locally to improve ability to wisely place volunteers.	X	
Develop rapport among participants.	X	X
Recruit volunteers with the knowledge, skills and aptitude to mentor.	X	
Align with local industry clusters, or select them for new programs.	X	X
Position volunteers as mentor-peers of students; no positions of authority.		X
Prioritize placing (qualified) volunteers in direct contact with students.		X
Use volunteers to activate or enhance constructivist learning.		X
View STEM professional volunteers as enabling affordances		X

Mentors should not be put in positions of authority, but rather should be positioned as mentor-peers of students to encourage discourse and other constructivist activities consistent with development of 21st century skills. Notwithstanding specific needs in local settings, educators should prioritize placing volunteer mentors in direct contact with students to encourage the aforementioned activities, and educators should put less emphasis on using volunteers behind-the-scenes. Educators and programs should consider using volunteer-mentors to activate constructivist learning within program settings.

In all activities, an eye toward what is practical should be maintained. The energy an educator spends—pedagogically, administratively, logistically, in every respect—must release more energy than that invested, or the approach cannot be sustained. Programs and educators should recognize STEM professional volunteers as enabling new affordances in their environment. Educators are professionals who understand when and how to access those affordances for best results.

5.3.2 Potential Future Research

Opportunities for future research derive from study findings, from elements of the study that lacked full clarity, and from expansion beyond the limits of the current study. The viewing of STEM professional volunteers as opening affordances also suggests future research possibilities. The Gamse et al. (2014) proposed research agenda was an effective structure within which study results could be considered, and it inspires consideration of models and what future hypotheses might be explored.

5.3.2.1 Confirming and Expanding Study Findings

The study's surveys and instruments proved useful in the current population. Future research could seek to use these surveys and instruments in other populations that use STEM professional volunteers. In doing so, an attempt could be made to better operationally define and discriminate between deployment practices. In particular, the practices of mentorship, helping students with projects, and speaking to students about careers appeared susceptible to overlapping interpretations.

As an adaptive measure to a lower-than-expected number of participants, I split the list of recruiting practices into three groups, and the list of deployment practices into two groups. These categorizes proved very useful and were reflected in study outcomes. One might ask if these outcomes were self-confirming. Factor analysis might prove insightful when data are collected in additional populations.

An especially productive direction might explore how practice-to-CLES-scale correlations unfold in other populations. With further study, knowledge and confidence might be gained regarding using this approach to help programs make better use of volunteers in their local context. Programs and educators might become more effective at deploying constructivist pedagogy and achieving learning outcomes. A more rigorous examination of the correlations might measure constructivism in programs by querying the program's students rather than its educators. More broadly, one might ask: Do STEM professional volunteers really open constructivist teaching and learning affordances that are difficult to open through other means? Such a finding, explored and confirmed in multiple settings, could support existing investments and lead to expanded investments in the use of STEM professional volunteers.

5.3.2.2 Affordances and Educator-Focused Models

The affordances opened by STEM professional volunteers are, in their fundamental nature, just like other classroom affordances that are derived from textbooks, teaching tools, pedagogical models, technology, etc. Future research could work to more sharply define the affordances opened by STEM professional volunteers. One should remember that affordances are not the tools themselves, but the complementarity of the object (in this case, the STEM professional volunteers) with the person served (educator and/or student) in context of the ecosystem (Gibson, 1986).

One might also consider how STEM professional volunteers fit with or assume a role within existing models for bringing tools and techniques into education. Two models covered in this study's literature review are the Concerns-Based Adoption Model (CBAM) (Hall & Hord, 1987) and Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006). One might use CBAM instruments to understand how the concerns of educators regarding volunteers unfold over time. One might adapt TPACK to become *VPACK* and explore how volunteers, pedagogy and content knowledge become integrated in teaching and learning, informed by lessons of the TPACK model.

5.3.2.3 STEM Professional Volunteers and Rapport

The emergence of rapport as a theme of the study, in light of the literature on rapport as a facilitator of learning (e.g., Jones et al., 2009) suggests directions for research. If STEM professionals bring rapport to secondary education, one might wish to learn how to maximize the effect. In addition, program settings like those in the current study might provide new opportunities to understand how rapport functions in secondary education.

5.3.2.4 Advancing the Gamse et al. (2014) STEM Corps Research Agenda

As argued, the STEM Corps research agenda of Gamse et al. (2014) has been advanced by this study. Nevertheless, I agree with Gamse et al. that little rigorous research has been performed focused on the use of STEM professionals as volunteers, and that a sustained research effort is needed to approach any generalizable conclusions about STEM professional volunteers. Further research should build on Gamse et al.'s work and on the current study. Practices should be further defined and discriminated. Models and hypotheses should be proposed and tested through qualitative and quantitative means. A sustained effort guided by an overall agenda is needed to understand the role of STEM professional volunteers in secondary education.

5.4 Conclusion

The current study explored the practices of educators when recruiting and deploying STEM professional volunteers. It explored the importance educators give to different recruiting and volunteer deployment practices, and it explored whether those practices might be related to constructivist teaching and learning in the programs under study. The study identified recruiting of parents, former students, and from local resources as the most valued recruiting approaches. The study surfaced how educators look for knowledge and skills in volunteers, and also how educators deployed volunteers in their programs in ways that are practical and build rapport among all program participants. When deploying volunteers, most educators placed the highest value on placing STEM professionals in close proximity to students. They set up volunteers as mentors who can drive constructivist teaching and learning practices with students. More broadly, I concluded that study of STEM professional volunteers should be made through the lens of the theory of affordances. As with any affordance, educators make professional decisions in their local context about whether and how to use STEM professional volunteers, and in that effort, they strive for efficient and otherwise optimal results.

The study was conducted within the philosophical context of critical theory, acknowledging an objective reality, but also providing room for researcher and subjects as advocates. The research methodology was exploratory and explanatory mixed methods, acknowledging the lack of prior rigorous study, and acknowledging that current results are not intended as generalizable, but rather should be read and transferred to one's local context under the critical eye of the reader. While significant empirical study was performed, and statistical rigor honored, results apply only within the current study context. Practically, the target populations of the San Antonio-area CyberPatriot program (the primary population), and of FIRST-Alamo Region educator-coaches, are atypical in important respects from most educators, and even from STEM educators as a whole. All interpretation should be made in full awareness of these characteristics of the study.

I choose to conclude with observations more difficult to support with data. I was struck by the caring nature of the educators with whom I had direct interaction during the conduct of the study. While these educators described the practical decisions they made while on the job, their first choice was certainly less practical—the choice to become coaches in the CyberPatriot or FIRST programs. This choice did not satisfy a demand of their job description. Rather, it reflected their values and their commitment to create great learning experiences for their students. I conclude that these educators care a great deal about their students. I exhort myself and others to be diligent, to be creative, and to find ways to support educators and the STEM professionals who go beyond the call to teach secondary students.

APPENDIX A

ITEST PROJECTS INCLUDING STEM PROFESSIONAL VOLUNTEERS

A search was performed using the National Science Foundation grant awards advanced search web page at http://www.nsf.gov/awardsearch/advancedSearch.jsp. The dates searched were October 1, 2008 to February 1, 2015. ITEST projects were downloaded, and project abstracts further searched for the keywords *adult*, *volunteer*, *industry*, *professional*, and *mentor*. The resulting list of abstracts was reviewed. The abstracts listed below indicated the use of STEM professional volunteers in the program described. Not all programs were named; names are provided for programs when provided by the abstract.

1. Challenge-based robotics, engineering and research program for middle and high school students in San Diego
2. Studio STEM, with engineering design activities for students in rural Appalachia
3. GRACE project, with GIS resources for students in Michigan
4. Acquainting Metro Atlanta Youth with STEM (AMAYS) program advancing STEM skills and ICT career interest
5. Computer science program for the College and Beyond after-school program sponsored by the Latin American Association
6. STEM Career Clubs program run by local school districts and North Carolina State University
7. FUSE Studios STEM and careers project in Chicago
8. Bioinformatics project with University at Buffalo Department of Biotechnical and Clinical Laboratory Sciences and the New York State Area Health Education Center System
9. Bits-2-Bytes program at the University of Minnesota
10. Water SCIENCE project involving Concord Consortium, Arizona State University, Stroud Water Resource Center, and Machine Science, Inc.
11. Project-based, socially relevant computing experiences to the University of Massachusetts Lowell (UML), the Tri-City Technology Education Collaborative Inc. (TRITEC), and the urban school districts of Medford and Everett, MA
12. SCI-TALKS, energy and environmental education programs in West Virginia

13. MATTS, marine technology in New England
14. Engineering and computer science, Cal State Fullerton and Anaheim Union High School District
15. SPARCS, integrating computer science into grades 7-9 math and science instruction.
16. Real-World Externships in Iowa
17. Network Science, computer network research, Boston University and the New York Hall of Science
18. University or Cincinatti regional partnerships
19. GLOBE, WestEd and University of California-Berkeley
20. SportsLab:2020, Nike and Sport Research Lab
21. Helping Native American and Hispanic students with STEM content in grades 3-8 in southern Arizona

APPENDIX B

CYBERTEXAS FOUNDATION 2016-2017 CYBERPATRIOT CALENDAR

CyberTexas Foundation Director Col. (Ret.) Chris Cook provided this calendar for San Antonio CyberPatriot Center of Excellence training activities and events for 2016-2017.

CP IX Registration Opens 04/01/16
SA Mayor's Cyber Cup Luncheon 2 Apr 2016

- @ Freeman Coliseum Exhibition Hall A 3201 E. Houston St.
- College Fair 10AM
- Awards Luncheon 11:30AM

CPVIII National Finals Competition 04/10/16 - 04/14/16

- (Hyatt Regency, Inner Harbor, Baltimore, MD)

National Collegiate Cyber Defense Competition 04/22-24/16
@ HBG Convention Center
CyberPatriot – Summer of Learning 04/30/16 @UTSA
UTSA Cyber Teacher PREP 06/06/16 - 06/10/16
UTSA-PREP GenCyber (Monday-Thursday) 06/13/16 - 07/28/16
Civil Air Patrol Cyber Clinic 06/10/16 - 06/18/16
UTSA/St. Philip's College GenCyber 06/20/16 - TBD
San Antonio College Cyber Defender Camp
SWISD Cyber Clinic 06/06/16 - 06/17/16, 06/20/16 - 07/01/16
Hallmark University Security + Bootcamps 06/13/16 - 06/24/16, 08/01/16 - 08/12/16
CP IX Exhibition Round 1 04/14/16 - 4/24/16
CP IX Exhibition Round 2 05/12/16 - 05/22/16
CP IX Exhibition Round 3 06/09/16 - 06/19/16
CP IX Exhibition Round 4 07/14/16 - 07/24/16
School's Out Hackathon. (SoHacks) 08/07/16 - 08/08/16
CP IX Exhibition Round 5 08/11/16 - 08/21/16
San Antonio CP IX Prep Clinic (Middle School) 09/12/16 SAC
San Antonio CP IX Prep Clinic (High School) 09/19/16 Rackspace
Registration Closes 10/09/16
CP IX Practice Round 10/13/16 - 10/27/16
Cyber Security 3 Day Start-up 10/16/16 - 10/18/16
San Antonio CP IX Prep Clinic (Middle School) 10/17/16 SAC
San Antonio CP IX Prep Clinic (High School) 10/24/16 Rackspace
CP IX Qualification Round 1 11/13/16 - 11/15/16
CP IX Qualification Round 2 12/04/16 - 12/06/16
San Antonio CP IX HS Prep Clinic (Semi-finals) 01/16/17 Rackspace
CP IX High School Elimination Round (State) 01/29/17 - 01/31/17
CP IX Middle School Practice Round 01/29/17 - 01/31/17
San Antonio CP IX MS Prep Clinic (Practice Round Semi-finals prep) 01/30/17 @SA College
CP IX High School Elimination Round (Regional) 02/19/17 - 02/21/17
CP IX Semi-finals (Middle School) 02/19/17 - 02/21/17
San Antonio CP IX Prep Clinic/Red Team 02/27/17 San Antonio College
Finals Practice Round 03/08/17 - 03/18/17

San Antonio CP IX Prep Clinic/Red Team 03/11/17 IPSecure
(for National Championship) at 903 Billy Mitchell Blvd Suite 110, SA, TX 78226
San Antonio Mayor’s 2017 Cyber Cup & College Fair TBD
National Championship TBD

APPENDIX C

PHASE 1 SURVEY

Studying How Educators Work With STEM Professional Volunteers
Educator Pre-Survey

This ten-minute pre-survey will help us sharpen the surveys to be used during the main phase of this study. Your participation will help us ask the right questions in the right ways.

Definition: In this survey, *"STEM professional volunteers"* refers to adults from outside your school who are helping you with STEM education efforts. These volunteers are assumed to bring industry or other relevant professional experience to your STEM education efforts.

Please confirm that you previously read the Informed Consent notice and agreed to participate in this study.

- ○ Yes, I read the Informed Consent notice and consented.
- ○ No, I did not read it (please close this survey and visit www.stemvolunteers.com).

Enter the pseudonym (unique ID) assigned to you for this study. REMINDER: It's an animal name.

[ ]

Page 2 of 5

As you answer the following narrative questions, please keep in mind that the initial questions are intentionally open-ended. More specific questions will be presented as the survey progresses.

List the reasons, if any, why you involve STEM professional volunteers in STEM education.

List the practices you use to find STEM professional volunteers.

List the different ways you use STEM professional volunteers. What kinds of things do you ask them to do?

Page 3 of 5

__Please answer Yes or No to the questions below__.

As you answer each question, we invite you to comment on whether question makes sense to you, and/or to suggest better or more standard ways to refer to each activity. Note usage of words, phrasing or concepts that are more consistent with how things are referred to in your organization. If the question is fine as is, no comments are needed.

NOTE: Seeing these questions might make you want to change your prior answers. **However, please do NOT revise your prior answers.** We asked those questions first so we can understand your viewpoint prior to any bias introduced by ours!

Do you contact large companies for STEM professional volunteers?

(Use the associated text field to leave comments about the question, or suggest alternate wording, phrasing or concepts. Leave blank if you have no comments.)

- ○ Yes [ ]
- ○ No [ ]

Do you contact medium-sized companies for STEM professional volunteers?

- ○ Yes [ ]
- ○ No [ ]

Do you contact small-but-established companies for STEM professional volunteers?

- ○ Yes [ ]
- ○ No [ ]

Do you contact startup companies for STEM professional volunteers?

- ○ Yes [ ]
- ○ No [ ]

Do you work through your own organization or program to find STEM professional volunteers?

○ Yes

○ No

Do you work your own personal contacts to find STEM professional volunteers?

○ Yes

○ No

Page 4 of 5

Do you have STEM professional volunteers present regarding their career fields?

○ Yes

○ No

Do you have STEM professional volunteers mentor students?

○ Yes

○ No

Do you have STEM professional volunteers help students with specific projects, ir formal or informal settings?

○ Yes

○ No

Do you have STEM professional volunteers help you understand application of content in their workplace?

- Yes ____
- No ____

Do you have STEM professional volunteers help you develop curriculum, and/or give you content suggestions that you include in curriculum?

- Yes ____
- No ____

Do you have STEM professional volunteers tutor students regarding their traditional, non-project coursework?

- Yes ____
- No ____

Do you have STEM professional volunteers host fields trips at their workplace?

- Yes ____
- No ____

Do you have STEM professional volunteers deliver formal teacher professional development, and/or host you (the educator, not the students) at their workplace, so you can better understand the application of what students are learning?

- Yes ____
- No ____

Do you have STEM professional volunteers directly deliver instruction to students in formal school day settings (for example, in your classroom)?

- Yes
- No

Page 5 of 5

Did this survey make sense to you? Please comment on anything you found unclear, confusing or incomplete in this survey, or any change we could make to make the survey more effective. If you found it clear, please say so!

Please list any additional practices you engage in that you did not mention above and that we did not ask about.

Click the green arrow button to the right to complete the survey. >>>>>

Powered by Qualtrics

APPENDIX D

PHASE 2A EDUCATOR SURVEY

Studying How Educators Work With STEM Professional Volunteers

Relative Importance of Educator Practices

This survey will help us understand the ***importance*** you give to different practices educators use to involve ***STEM professional volunteers*** in STEM education. We estimate you will need 15 minutes to complete the survey.

Please confirm that you previously read the Informed Consent notice and agreed to participate in this study.

- ○ Yes, I read the Informed Consent notice and consented.
- ○ No, I did not read it (please close this survey and visit www.stemvolunteers.com).

Enter the pseudonym (unique ID) assigned to you for this study. REMINDER: It's an animal name.

BACKGROUND

What do we mean by "*importance?*"

- If a practice is important to you, you spend time on it, you prioritize it compared to other things you might spend your time on, and you find value in the outcomes of the practice.
- If you do not spend time on a practice, it is **not important** to you.
- Maybe you wish you had time? That rates slightly higher, but just a little.
- If you spend time on something but wonder whether it's worthwhile, then it's **somewhat important** to you.
- If you spend time on a practice and could not imagine stopping in the future, the practice is **very important** to you.
- *The exact amount of time you spend on a practice is not always primary. Think about both time and the value of the outcomes you achieve.*

What do we mean by "*STEM professional volunteers?*"

- In this survey, "***STEM professional volunteers***" refers to adults from outside your school who are helping you with STEM education efforts. These volunteers are assumed to bring industry or other relevant professional experience to your STEM education efforts.

Use the arrow button (">>") to continue.

SURVEY PART 1 OF 3 – RECRUITING VOLUNTEERS

We would like to learn about how you find STEM professional volunteers. To help you answer the questions in this section, please familiarize yourself with these descriptions of ways educators recruit.

Recruiting professionals from industry (for-profit)

- **Recruit from large companies** (1000+ employees)
- **Recruit from medium companies** (100-999 employees)
- **Recruit from small-but-established companies** (1-100 employees)
- **Recruit from startups**

Recruiting professionals from outside industry

- **Recruit from government employers** (includes military)
- **Recruit from** institutes of **higher education** (colleges, universities)
- **Recruit from non-profits**

Other recruiting methods

- **Recruit through your host organization** (For example, do you rely on local or national organizations to find your volunteers? For those in CyberPatriot or FIRST, this refers to your local organizations.)
- **Recruit using your network**/personal contacts
- **Recruit parents** of your students who are STEM professionals
- **Recruit former students** who are now STEM professionals

Please rate the importance of each recruiting practice from 1 to 10, with 10 being most important. Select one number for each practice.

Recruit STEM professional volunteers from large companies.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Recruit STEM professional volunteers from medium companies.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Recruit STEM professional volunteers from small-but-established companies.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Recruit STEM professional volunteers from startups.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Recruit STEM professional volunteers from government employers.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Recruit STEM professional volunteers from higher education.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Recruit STEM professional volunteers from non-profits.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Recruit STEM professional volunteers through your host organization.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Recruit STEM professional volunteers using your network.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
◌	◌	◌	◌	◌	◌	◌	◌	◌	◌

Recruit parents.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
◌	◌	◌	◌	◌	◌	◌	◌	◌	◌

Recruit former students.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
◌	◌	◌	◌	◌	◌	◌	◌	◌	◌

Comparisons

You will now be asked to compare pairs of recruiting practices, answering which is most important to you. This may seem repetitive, but it's a research technique that gives us greater insight.

Please don't refer to your prior answers! Just react to each comparison. Mark the box of the practice you wish to select, for each comparison.

Which practice is most important to you? Choose one from each pair:

- ◌ Recruit from large companies (1000+)
- ◌ Recruit from medium companies (100-999)

- ◌ Recruit from small-but-established companies (1-99)
- ◌ Recruit from large companies

- ◌ Recruit from large companies (1000+)
- ◌ Recruit from startups

- ◌ Recruit from medium companies
- ◌ Recruit from small-but-established companies

- Recruit from startups
- Recruit from medium companies

- Recruit from small-but-established companies
- Recruit from startups

- Recruit from industry (for-profit companies)
- Recruit from government employers (includes military)

- Recruit from higher education
- Recruit from industry

- Recruit from industry
- Recruit from non-profits

- Recruit from higher education
- Recruit from government employers

- Recruit from government employers
- Recruit from non-profits

- Recruit from non-profits
- Recruit from higher education

- Recruit through your host organization (e.g., CyberPatriot, FIRST)
- Recruit using your network (personal contacts)

- Recruit parents (of your students)
- Recruit through your host organization

- Recruit through your host organization
- Recruit former students

- Recruit parents
- Recruit using your network

- Recruit using your network
- Recruit former students

○ Recruit former students

○ Recruit parents

Were the recruiting questions clear? If you found anything confusing, please comment specifically. Also share any comments you have, or practices you think we missed.

SURVEY PART 2 OF 3 – WHAT VOLUNTEERS DO

We would also like to learn about how you use STEM professional volunteers in formal and informal settings. To help you answer the questions in this section, please familiarize yourself with the descriptions below of some different ways educators use volunteers.

Working with students

- **Speak to students about careers**
- **Mentor students** (consistent volunteering, over time, intent to impact outcomes)
- **Help students with projects** (in formal or informal settings)
- **Directly teach content to students**
    - *This refers to volunteers teaching* ***subject matter content****, including cases where they are teaching content beyond your current level of knowledge.*
- **Host field trips**
- **General assistance** (be present, answer questions, help where needed)

Helping the teacher

- **Help you** (the teacher) **understand workplace application** of content
- **Develop curriculum / suggest** curriculum **content**
- **Deliver and/or host PD** (professional development)
- **Secure resources** (equipment, money) for program
- **Equipment setup, configure, maintain**

Please rate the importance of these volunteer activities from 1 to 10, with 10 being most important. Select one number for each practice.

Speak to students about careers.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Mentor students.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Help students with projects.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Directly teach content to students.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Host field trips.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

General assistance.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Help you understand workplace application.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Develop curriculum / suggest content.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Deliver and/or host PD.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Secure resources.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Equipment setup, configure, maintain.

NOT Important 1	2	3	4	5	6	7	8	9	VERY Important 10
○	○	○	○	○	○	○	○	○	○

Comparisons

You will now be asked to compare pairs of activities, answering which is most important to you.

Please don't refer to or change your prior answers! Just react to each comparison. Mark the box of the practice you wish to select, for each comparison.

Which practice is most important to you? Choose one from each pair:

○ Speak to students about careers
○ Mentor students

○ Help students with projects
○ Speak to students about careers

○ Speak to students about careers
○ Directly teach content to students

○ Host field trips
○ Speak to students about careers

○ Speak to students about careers
○ General assistance

○ Help students with projects
○ Mentor students

○ Mentor students
○ Directly teach content to students

○ Host field trips
○ Mentor students

○ Mentor students
○ General assistance

○ Directly teach content to students
○ Help students with projects

○ Help students with projects
○ Host field trips

○ General assistance
○ Help students with projects
○ Directly teach content to students
○ Host field trips

○ General assistance
○ Directly teach content to students

○ Host field trips
○ General assistance

○ Help you understand workplace application
○ Develop curriculum / suggest content

- Deliver and/or host PD
- Help you understand workplace application

- Help you understand workplace application
- Secure resources

- Equipment setup, configure, maintain
- Help you understand workplace application

- Develop curriculum / suggest content
- Deliver and/or host PD

- Secure resources
- Develop curriculum / suggest content

- Develop curriculum / suggest content
- Equipment setup, configure, maintain

- Secure resources
- Deliver and/or host PD

- Deliver and/or host PD
- Equipment setup, configure, maintain

- Secure resources
- Equipment setup, configure, maintain

Were the volunteer activity questions clear? If you found anything confusing, please comment specifically. Also share any comments you have, or practices you think we missed.

SURVEY PART 3 OF 3 – WRAP-UP

For each question, mark the choice that best applies.

Is word of mouth sufficient for your recruiting? In other words, do volunteers just come to you and proactively volunteer?

- ○ Yes, and that fills my volunteer needs.
- ○ Yes, I receive many volunteers this way.
- ○ Yes, I receive some volunteers this way, but not enough.
- ○ Yes, but I just receive a few volunteers this way.
- ○ No.

Do parents who are STEM professionals approach you proactively to volunteer?

- ○ Yes, many
- ○ Yes, some
- ○ Yes, a few
- ○ No

Select the statement which best reflects your situation.

- ○ I want STEM professional volunteers, and I have enough volunteers.
- ○ I want STEM professional volunteers, and I really need more.
- ○ STEM professional volunteers are not important to me, but I have some anyway.
- ○ STEM professional volunteers are not important to me, and I don't have any.

Please list any important additional practices you engage in that we did not ask about.

Please comment on anything you found unclear, confusing or incomplete in this survey, or any change we could make to make the survey more effective.

DEMOGRAPHICS

Your age:

- 18-25
- 26-35
- 36-45
- 46-55
- 56-65
- 66-75
- 76-85
- 85+
- Prefer not to answer

Your program

- CyberPatriot
- FIRST
- Other (please name) ______

School size, by number of students

- Under 500
- 500-999
- 1000-1999
- 2000-2999
- 3000+

School setting

- Urban
- Suburban
- Rural

Title I school?

- Yes
- No

Thank you! USE THE ARROW BUTTON (">>") TO COMPLETE THE SURVEY.

APPENDIX E

PHASE 2B CLES INSTRUMENT

Studying How Educators Work With STEM Professional Volunteers

How Students Learn in Your Program

This survey asks questions that will help us understand how student learning is happening in the activity/program under study (e.g., CyberPatriot, FIRST). In turn, we can then explore how the presence of STEM professional volunteers relates to the ways students learn. These survey questions are adapted from an established instrument previously completed by 10,000+ people worldwide. This survey should take you less than ten minutes to complete.

Please confirm that you previously read the Informed Consent notice and agreed to participate in this study.

- Yes, I read the Informed Consent notice and consented.
- No, I did not read it (please close this survey and visit www.stemvolunteers.com).

INSTRUCTIONS

Enter the pseudonym (unique ID) assigned to you for this study. **REMINDER**: It's an animal name.

INSTRUCTIONS

1. **This is not a test!** There are no right or wrong answers. Your opinion is what is wanted.

2. As you read the questions, the context for the questions is "the program under study at your school"; for example, CyberPatriot at your school, or FIRST at your school.

3. We want you to answer these questions from the perspective of a student. Guidance:

   - Ask yourself: "How would a student in the program answer?"
   - Consider having a specific, typical student in mind. **For example, if Mary Garcia is a typical student in your class/group, think about how Mary would answer, and provide that answer.**

4. On the next few pages, you will find 20 sentences. For each sentence, mark only one selection corresponding to your answer. For example, for the question below...

In Your Program...	*Almost Always*	*Often*	*Sometimes*	*Seldom*	*Almost Never*
The teachers asks me questions	O	O	O	O	O

   - If Mary would answer *Often*, mark the *Often* column (as in the example above).
   - If Mary would answer *Never*, mark the *Almost Never* column.
   - Mark any one column.

5. **To change your answer**, simply mark the correct column.

Use the arrow button (">>") to continue.

Ready to begin? Please provide one answer for every question (row) below by marking the column of your choice for each row.

Learning about the World -- *How would a student answer?*

Remember to keep the student perspective!

	Almost Always	Often	Sometimes	Seldom	Almost Never
Students learn about the world outside of school.	○	○	○	○	○
Students' new learning starts with problems about the world outside of school.	○	○	○	○	○
Students learn how science can be part of their out-of-school life.	○	○	○	○	○
Students get a better understanding of the world outside of school.	○	○	○	○	○
Students learn interesting things about the world outside of school.	○	○	○	○	○

Learning to Speak Out -- *How would a student answer?*

Remember to keep the student perspective!

	Almost Always	Often	Sometimes	Seldom	Almost Never
It's OK for students to ask the teacher "why do I have to learn this?"	○	○	○	○	○
It's OK for students to question the way they're being taught.	○	○	○	○	○
It's OK for students to complain about activities that are confusing.	○	○	○	○	○
It's OK for students to complain about anything that prevents them from learning.	○	○	○	○	○
It's OK for students to express their opinion.	○	○	○	○	○

Learning to Learn -- ***How would a student answer?***

Remember to keep the student perspective!

	Almost Always	Often	Sometimes	Seldom	Almost Never
Students help the teacher to plan what they're going to learn.	○	○	○	○	○
Students help the teacher to decide how well they are learning.	○	○	○	○	○
Students help the teacher to decide which activities are best for them.	○	○	○	○	○
Students help the teacher to decide how much time they spend on activities.	○	○	○	○	○
Students help the teacher to decide which activities they do.	○	○	○	○	○

Learning to Communicate -- ***How would a student answer?***

Remember to keep the student perspective!

	Almost Always	Often	Sometimes	Seldom	Almost Never
Students get the chance to talk to other students.	○	○	○	○	○
Students talk with other students about how to solve problems.	○	○	○	○	○
Students explain their ideas to other students.	○	○	○	○	○
Students ask other students to explain their ideas.	○	○	○	○	○
Students listen carefully to other student's ideas.	○	○	○	○	○

Please comment on anything you found unclear, confusing or incomplete in this survey, or any change we could make to make the survey more effective.

<ins>**USE THE ARROW BUTTON (">>") TO COMPLETE THE SURVEY.**</ins>

Adapted from http://surveylearning.moodle.com/mod/survey/view.php?id=117.

Taylor, P. C., Fraser, B. J., & White, L. R. (1994). CLES: An instrument for monitoring the development of constructivist learning environments. In *Annual Meeting of the American Educational Research Association, New Orleans, LA.*

APPENDIX F

PHASE 3 SEMI-STRUCTURED INTERVIEW SCRIPT

Overall guidance for interview

1. Primary questions:
    a. Why RecruitFormerStudents and RecruitParents is high.
    b. Why ActionMentor* and ActionProjects is high.
    c. Why they correlate most to constructivist learning outcomes.
2. Secondary questions:
    a. Why RecruitGovernment high (theory – San Antonio is Military and Cyber City USA)
    b. Why RecruitSmallCompanies most interesting industry size.
    c. Why ActionSetup, ActionPD, ActionFT low.
    d. Why CLESLearn low.

NOTES ABOUT PARTICIPANT AND SCHOOL:

- Capture notes here.

Script (Give priority to questions that address the primary items listed above)

1. Confirm Informed Consent.
2. You rated RecruitFormerStudents at N. Why?
    - Why (higher/lower) than others?
3. You rated RecruitParents at N. Why?
    - Why (higher/lower) than others?
4. In general, recruiting through local/personal/program resources was higher than recruiting industry, government, non-profits. Why?
5. You rated ActionMentor at N. Why?
6. You rated ActionProjects at N. Why?
7. (Refer to handout.) Does anything surprise you about these Recruiting ratings?
8. (Refer to handout.) Does anything surprise you about these Volunteer Deployment ratings?
9. Does it make sense to you that RecruitParents would correlate to CLES World? Why or why not?
10. Does it make sense to you that ActionsMentor would correlate to CLES Comm? Why or why not?
11. Does it make sense to you that ActionsMentor would correlate to CLES Speak? Why or why not?
12. Why might SchoolSize correlate to CLES Speak?
13. Does it make sense to you that RecruitParents would correlate to CLES World? Why or why not?
14. Why would RecruitGovernment correlate to how you teach / constructivist teaching in the program?
15. Why would RecruitFormerStudents correlate to how you teach / constructivist teaching in the program?
16. Why would ActionsProjects correlate to how you teach / constructivist teaching in the program?
17. Anything else we should discuss?

*The prefix *Action* refers to volunteer deployment activities. These shorthands were translated to meaningful phrases when used during interviews.

APPENDIX G

PHASE 3 INTERVIEWEE HANDOUT

This handout was emailed to each interviewee immediately (minutes) prior to the start of their interview. I used this handout to receive reaction to the ratings and feedback regarding the ranking of the practices. Color coding corresponds to the pairwise comparison groupings. I explained color coding to the interviewee.

STEM Professional Volunteers Study

Phase 3 Interview Handout

Recruiting, Likert

Former students	8.25
Parents	7.92
Government	7.08
Through host	7.08
Personal net	6.88
Small companies	6.71
Higher ed	6.50
Large companies	6.38
Medium companies	6.29
Non-profits	5.58
Startups	5.50

Deployment Actions, Likert

Mentor students.	**9.21**
Speak to students about careers.	**8.38**
Help you understand workplace application.	**7.42**
Help students with projects.	**7.21**
Directly teach content to students.	**7.08**
Secure resources.	**7.04**
General assistance.	**6.42**
Develop curriculum / suggest content.	**6.42**
Equipment setup, configure, maintain.	**5.79**
Deliver and/or host PD.	**5.71**
Host field trips.	**5.13**

APPENDIX H

PHASE 3 CODES, COMPLETE LIST

All codes generated from Phase 3 are listed below. Codes above the first line are also in the main text, and an extended description is provided. Codes below the line are shown with their symbolic name as used by the coders.

Code	Count
Evidence of affordance	35
Accessibility is important	16
Mentoring is related to pedagogy	10
Direct contact with students is important	6
Teacher is not meant to be technical expert	6
Technical knowledge is important	5
Highly value parents with technical knowledge	5
The meaning of *project* was unclear	4
Teacher's role is as manager of learning	4
Parents have and effectively share real world experience	4
Mentors must bring and share technical knowledge	4
Parents are especially motivated	3
Parents especially contribute to pedagogy	3
Mentors are role models for students	3
former student role model	2
aff effectiveness at competition	2
teacher life experience	2
parent accessible	2
program support	2
aff social capital for low SES	2
constructivist pedagogy	2
role model and pedagogy	2
large school bad for speaking out	2
industry cluster	2
equipment lower	2
former student tech knowledge	2
parent important	2
former student with pro	1
parent relationship	1
aff familiar	1
mentor good with kids	1
volunteer fit	1
mentor career	1
mentor pipeline	1
volunteer-student relationship	1
prof as role models	1
industry sponsor team	1

Code	Count
back end support prospect	1
large school more class mgmt	1
mentor life experience	1
interschool support	1
government is local	1
competition success	1
host field trips higher	1
large company active	1
PD lower	1
PD saturation from other classes	1
parent effective	1
mentor pedagogy	1
small school program support disadvantage	1
school schedule	1
former student pipeline	1
former student important	1
regional priority	1
mentor motivated	1
no of volunteers limited	1
mentor important	1
small company accessible	1
mentor atmosphere	1
industry and pedagogy	1

APPENDIX I

THIRD PARTY TRADEMARKS

FIRST®, WASTE WISE℠, TRASH TREK℠, FIRST® RES-Q℠, and Coopertition® are marks of FIRST.

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