A Multiple Case Study of an Interorganizational Collaboration: Exploring the First Year of a
Public-Private Partnership Focused on Secondary STEM Education

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ABSTRACT

National calls for improving the prospects of STEM workforce development and broadening participation in STEM place the focus of change within the education system. Despite many efforts towards integrating STEM, and specifically engineering, into pre-college settings, mechanisms for change in schools towards these goals remain underdeveloped. While collaborative solutions involving multiple organizations across sectors towards addressing this complex problem appear promising, more work is needed to develop a critical understanding of the processes involved when such different organizations come together to collaborate towards a social goal. Based in an effort to bring more theoretical literature into the discourse around school-university-industry partnership, the purpose of this research is to contribute to a better understanding of how K-12 STEM interorganizational relationships develop in their initial stages by focusing on the collaborative processes and structures and to develop implications for future success of such collaborations.

To accomplish this, I used a multiple case study design to investigate the collaborative processes that emerged in the first year of the partnership within VT PEERS (Virginia Tech Partnering with Educators and Engineers in Rural Schools). I centered my analysis on select adult stakeholders in the collaborative problem who were also programmatic participants including teachers, administrators, industry partners, and university affiliates. Using pre-year and post-year semi-structured interviews with these stakeholders, I characterized the collaborative processes in the first year of the program. Interpretation of results comparing across cases indicated considerations for education and organizational theory literature as well as implications for collaborative practice.

Findings confirmed the emergent and negotiated nature of interorganizational collaboration and highlighted the importance of managing communication and reflection in partnership. Organizational culture may impact capacity building when organizations come together towards a complex social goal, particularly when industry is involved, and autonomy and operational issues within the school system and teaching can make collaborating with schools particularly challenging. When organizations come together towards a social goal centered around one of the collaborative partners, equality in exchange may not be a good measure of success. With the caveat that communication needs to be well managed to build credibility among partners, an unequal but equitable exchange of resources may be appropriate in collaborations towards a social goal. While it is tempting to continue to measure quality in interorganizational collaborations narrowly by the outcomes produced, a macro-level look at the collaborative processes involved enables collaborative stakeholders to be intentional about designing for future success.
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GENERAL AUDIENCE ABSTRACT

National calls for a higher number and greater diversity of STEM professionals place the burden of change on school systems. Despite some successful efforts, there still remains significant challenges to making change in schools. Partnerships between private companies, universities, and school systems appear promising, but current work is limited in its conclusions. There is a need to reflect more critically on the process of how organizations build relationships in addressing social goals if we are to gain a better understanding of how to make these partnerships successful.

To address this, I conducted pre-year and post-year interviews with teachers, administrators, industry partners, and university affiliates during the first year of VT PEERS (Virginia Tech Partnering with Educators and Engineers in Rural Schools). Because the project took place in three different rural school counties, I looked for similarities and differences across the collaborations in each county to build a broader understanding and develop implications for other partnerships.

Findings from this study led to several important takeaways about collaborating across organizations towards goals in K-12 STEM. First, collaboration is a process and initial plans will change and develop over time. Reflecting on this and keeping open communication through changes potentially equips collaborators to better weather the ups and downs of partnership. Second, the nature and flexibility of an organization’s work environment impacts how much tension they feel between getting their everyday work done and contributing to the collaboration. Third, unequal costs and benefits may be acceptable in a collaboration as long as collaborators are in agreement on the balance. Again, communication is important to build trust and understanding among partners for a healthy balance to be achieved. Overall, taking a birds-eye view of collaborative processes allows collaborators to be more intentional about designing for future success.
Dedication

Dedicated to my wife, Jennifer Gillen, for her love, encouragement, and sacrifice.
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Chapter 1. Introduction

An enormous task has fallen to our teachers and school systems as national calls for renewed efforts to improve STEM workforce development coincide with a movement within school systems to promote more STEM content, particularly engineering. These educators already work into the night, over 10 hours a day and 50 hours per week (Scholastic and the Bill and Melinda Gates Foundation, 2012). The burden of exploring new engineering standards in particular and also applying them in the context of traditional school disciplines (e.g., math, science, social studies) has become unreasonable. It has also been argued that a disconnect between the competencies emphasized in education versus the workplace is a “misalignment between K-12 and postsecondary science curricula” (ACT & Business Higher Education Forum, 2014, p. 3). Thus, it is no surprise that attempts to address this gap include limited but promising university-mediated efforts to establish partnerships among STEM professionals from industry, school systems, and the professional educators employed by them. However, existing research in this context does not explore dimensions of interorganizational collaborations that the more theoretical literature would suggest would be important to ensuring long-term success (e.g., mutual benefits, joint goal development). Research that takes into account the broader body of knowledge on collaboration is not prevalent in the K-12 STEM context for these sorts of cross-sector partnerships.

The purpose of this dissertation research is to build an understanding of how interorganizational relationships centered around K-12 STEM develop and change during the initial stages of a structured collaboration and to advance collaboration theory and practice. The characterization of collaboration as an emergent process (Gray, 1989) in Chapter 2 suggests that the initial stages of the collaboration are particularly important to study. This work also has significance for future collaborations in similar contexts to the NSF-funded project based in rural Virginia as discussed.

In Chapter 1, I motivate the research, explain the need and purpose of the study, and argue why it has broader significance. The following sections outline how national calls to action and literature on collaboration support the importance of this research. An overview of the NSF-funded project in which this research takes place is also provided and broader significance is discussed.
**Problem Formulation**

There are four main pieces to the problem formulation for the research. First, I explain why people study K-12 engineering education and the national calls to action related to STEM content and STEM workforce development in schools. Second, I present how the current mechanisms for change (e.g., teacher professional development) are varied and deficient in terms of addressing these calls to action. Third, I argue why collaborations involving education systems and industry might help alleviate some of these concerns. Fourth, I maintain that this research is necessary given the current landscape of interorganizational collaboration research in the K-12 STEM context.

**(1) The national discourse around STEM workforce development and K-12 engineering education.** Integrating engineering into K-12 education has been motivated by the goals of developing a better understanding of different pathways to engineering careers, building students’ engineering and technological literacy from a young age, and exploring the possibilities of blending engineering with traditional subjects to enhance learning (Cunningham & Lachapelle, 2014). Looking more broadly, national calls to make changes in K-12 education towards the goal of creating a “STEM-capable workforce” are not new (Committee on Integrated STEM Education, National Academy of Engineering, & National Research Council, 2014). Recently, this has meant considering the development of our nation’s technical workforce through non-bachelor degree pathways, and industry partnerships have been part of this expanded national agenda (Committee on the Supply Chain for Middle-Skill Jobs: Education, Training, and Certification Pathways et al., 2017). At the same time, teachers are feeling pressure from outside sources to focus more deeply on career readiness and introducing students to STEM subjects as they pertain to careers in engineering and technology. For example, in 2017 alone, the STEM Education Coalition has tracked dozens of legislation either introduced or passed in the United States Senate and House of Representatives related to STEM education and career pathways (STEM Education Coalition, 2017). As part of this national discourse, state-led initiatives developed the Next Generation Science Standards that include engineering (NGSS Lead States, 2013) aligned with the National Research Council’s Framework for K-12 Science Education (National Research Council, 2011). These were developed by states in conjunction with National Science Teachers Association and the American Association for the Advancement of Science. Prior to the release of the NGSS in April 2013, only six states had explicit
engineering standards (Carr, Bennett, & Strobel, 2012), but this number is steadily growing. With the adoption of the NGSS by Hawaii in February, 2016, 18 total states and Washington DC have officially adopted the NGSS standards, including their engineering-specific standards (Heitin, 2016). These standards represent a turning point in the national STEM discourse as multiple states agree that engineering should be in K-12 schools.

(2) Problems with current mechanisms for change. One immense challenge that emerges in addressing the national calls is that formal mechanisms for making these changes are varied and deficient. We will need well-prepared educators to address these learning outcomes as the adoption of NGSS standards and engineering standards like them continues. However, teachers are under-resourced, under-supported, and research suggests they are underprepared to meet these challenges. Most recently, Antink-Meyer and Meyer (2016) investigated elementary and high school teachers’ misconceptions related to science and engineering practices. Using multimedia representations of science and engineering practice and professional development (PD) activities, they found misconceptions in teacher reflections. Similar struggles in decoding engineering content for quality lessons occurred in the middle school classroom investigation conducted by Judson, Ernzen, Krause, Middleton, and Culbertson (2016). Of the four categories of lessons developed from NGSS standards, about half of the middle school lessons developed in their study fell into the “Vague and/or Overly Broad” category (p. 7). Online teacher support communities such as TeachEngineering.org have begun to align their lessons with the NGSS in hopes of alleviating these issues, but research suggests that coverage of the standards is limited in these instances, compromising the usefulness of the online support communities. For example, seventy-five percent of the NGSS represent only 15 of the TeachEngineering.org lessons while over 100 TeachEngineering.org lessons represent only three frequently used standards (Samson, Sullivan, Reitsma, & Soltys, 2015).

Understandable in the face of competing demands, pre-service teacher education in the United States also struggles to prepare teachers to meet these national calls. Fixing problems with pre-service teacher education is an old call for reform (e.g., Weis, 1989) that still remains a prominent issue today. The National Council on Teacher Quality (2017) found less than half of the secondary teacher undergraduate preparation programs they analyzed covered both the acquisition of content knowledge and how to teach specific content knowledge. Neither content knowledge without pedagogy nor pedagogy without content knowledge are enough to prepare a
teacher for success in the classroom. Professional development for in-service teachers would seek to supplement the deficiencies of teacher preparation programs but modern professional development practices also leave much to be desired, such as lack of support during implementation of new pedagogy or knowledge (Gulamhussein, 2013). Secondary science teachers in particular are more likely to have entered into teaching through alternative methods as opposed to traditional university training (Committee on Strengthening Science Education through a Teacher Learning Continuum et al., 2016). Teachers in such programs might have nontraditional (i.e., non-science) backgrounds. While it is not necessarily a shortcoming to have a diversity of background knowledge, teachers from nontraditional tracks may feel particularly underprepared to address engineering.

(3) **A collaborative solution.** Partnerships among school systems, engineers, and researchers may help alleviate issues of teacher preparedness, while supporting national STEM workforce development objectives. Individualism or the desire to feel self-reliant in their own classrooms and effective isolation from other educational professionals in their practice are also aspects of teaching culture (Hargreaves, 1993), and these findings have been used to support the idea of collaboration in teacher learning (Duncan-Howell, 2010). At face value, these cross-sector connections make sense, and industry-community partnerships have the potential for shared benefits (Googins & Rochlin, 2000). Teachers as participants in research on collaborations involving public school systems and industry have reported favorable outcomes for student learning (Rogers & Cejka, 2006). Additionally, industry partnership in K-12 schools presents opportunities for students to see career pathway options in engineering and technology outside of a traditional undergraduate program. Many engineering firms hire employees with education ranging from high school equivalency to PhDs in areas such as manufacturing, research, and design. However, there is still much room for expansion of our understanding of how these collaborations work in the often-complicated day to day operations of a school or classroom and in the context of broader institutional factors. Moreover, if we are asking school systems and teachers to adopt what amounts to yet another educational innovation in their classroom, we should dedicate time to make sure that any adjustment to educational practice is based in quality research.

(4) **The need for the study.** The empirical work on interorganizational collaborations in the K-12 STEM context is primarily descriptive or emphasizes teaching and learning outcomes
(e.g., Buxner et al., 2014; Hamos et al., 2009; Pawloski, Standridge, & Plotkowski, 2011; Rogers & Cejka, 2006), or they focus on specific dimensions of collaboration such as mutual benefits (e.g., Radinsky, Bouillion, Lento, & Gomez, 2001). These works fall short of building new interpretations about the underlying relationships and connections that the literature on collaboration would suggest might be important to explore for the ultimate success of those collaborations. Thomson, Perry, & Miller (2007) provide one such framework that I will elaborate upon and support with additional collaboration literature in Chapter 2. Furthermore, Rogers and Cejka (2006), from their research on a partnership involving Tufts University, engineers from industry, and K-12 teachers, suggest that further exploration of how these sorts of partnerships affect industry is important noting possible factors of importance specific to industry. There is a need for empirical work that interprets interorganizational collaborations in the context of K-12 STEM education but through a lens of the theoretical collaboration literature. This will allow conclusions to be made about the partnership beyond looking at easily measurable programmatic outcomes.

Study Context: NSF ITEST Project

This dissertation work takes place within a larger research and outreach project titled Virginia Tech Partnering with Educators and Engineers in Rural Schools (VT PEERS). It is funded through the National Science Foundation (NSF) Innovative Technology Experiences for Students and Teachers (ITEST) program. ITEST projects research the design, development, and implementation of innovative efforts to expand awareness of, motivation for, and knowledge about STEM careers (National Science Foundation, 2017). The outreach and research efforts are motivated by the idea that there are barriers for rural and Appalachian students to pursue engineering careers. Based on this, the goals of the project are two-fold:

(1) Increase Youth Awareness of, Interest in, and Readiness for Diverse Engineering Related Careers and Educational Pathways.

(2) Build Capacity for Schools to Sustainably Integrate Engineering Skills and Knowledge of Diverse Engineering-Related Careers and Educational Pathways.

To accomplish these goals, the project brings together middle school teachers from three rural school divisions and volunteers from engineering industry to design and implement hands-
on, standards-aligned, and locally-relevant engineering lessons over three years. Researchers mediate these interactions and also implement the lessons in the classroom with the teachers. In the first year, the project has served approximately 700 youth, every sixth-grade student across seven schools in three counties. Participants in the research include county administrators, principals, teachers, university affiliates, and middle school students. The VT PEERS study and the researcher role in this project will be elaborated on in Chapter 3.

**Purpose of the Study and Summary of the Research Design**

I have identified several unique challenges facing school systems as pressure increases to integrate engineering and consider workforce development initiatives in school curriculum. I have also suggested that partnerships between industry and school systems may help mitigate some of these challenges for teachers and school systems. Studying collaboration as an emergent phenomenon in the initial stages of an interorganizational partnership is critical to establishing factors of success towards sustainability. Therefore, the purpose of this research is to contribute to a better understanding of how interorganizational relationships centered around K-12 STEM develop and change during the initial stages of development and the implications for future collaborative success. In doing so, it will advance the literature on K-12 engineering education and industry collaborations and bring a much-needed theoretical perspective to the practically motivated literature on interorganizational collaboration in the K-12 STEM context. Informed by frameworks of collaboration presented in Chapter 2, I addressed the following sequential research questions:

1) **How do stakeholders characterize the collaborative processes in each county-level partnership?**
2) **What collaborative processes emerge across these county-level characterizations within the broader VT PEERS project?**

To address the research questions, I conducted a multiple case study design based on an adaptation of the guidelines from Yin (2014). Case study research is appropriate for studies in which the context is difficult to separate from the phenomenon (Yin, 2014; Stake, 2006). The study of the evolution of an interorganizational collaboration over the first year is impossible to remove from its real-world context. In this study, the sources of data were pre-year and post-year
interviews with different stakeholders in the collaboration across four stakeholder groups: teachers, administrators, industry partners, and university affiliates. Analysis was structured into three stages: (1) coding of individual interview transcripts, (2) building a case by looking across stakeholder interpretations within initial coding categories, and (3) cross-case synthesis considering the case interpretations made in the second step. More detail of each of these stages and justification for each aspect of the research design is provided in Chapter 3.

**Significance of the Research**

Beyond the knowledge contributions discussed, the conclusions of this study may benefit a variety of stakeholders along the engineering career pathway/pipeline. This research focuses on the volatile first year and the collaboration itself. For this reason, it has meaning for other organizations looking to establish similar partnerships in K-12 STEM but is not limited to the specific context of the middle school science classroom.

**Impact on the VT PEERS Project.** This study will help the ongoing VT PEERS project achieve their aims and gain valuable insight towards improving sustainability of the project after funding concludes. Intended results of the broader project include motivating teachers to integrate more engineering into their classroom and developing a better understanding of the teacher perspective. Findings from this study contribute to an understanding of how teachers view the impact of partnership on their professional practice. Reflecting in this way, teachers may also feel more motivated to consider how engineering fits into a traditional science curriculum. The VT PEERS project also seeks to establish collaborations between school and industry that grow and persist after the project is over. The results of this study help inform what a school-university-industry partnership looks like and the significance of classroom, school, or other contextual factors that play a role. Since the project is ongoing, these insights could be used to inform researcher actions in future years. For example, one finding from this study is related to the emergence of key individuals that facilitate collaborative processes. Identifying these individuals and communicating their importance to the long-term goals of the project might be a consideration for improving VT PEERS moving forward.

**Broader Impact.** This research yielded more information about how best to empower partners to play their part in sustaining partnerships, and also provided additional insight into how industry sees their role in these collaborations. Stadler (2011) stresses the importance of
managers considering potential conflicts of interest between business and social goals and establishing links between them whenever possible. It is hard to ignore the obvious conflicts that may arise when corporations agree to provide some of their resources such as people, money, or equipment to a K-12 school. An industry involved in a collaboration such as this would be asked to provide employees to spend time involved in collaborative activities. It would be optimal if these activities could somehow align with business goals, but this may not be the case. In discussing collaboration among K-12, university, and industry partners, Bruning (2003) calls on future researchers to consider why there is evidence that industry agrees that getting involved in K-12 education has value but participation in these sorts of activities lags. Exploring the first year of a partnership, how perceptions change from the start, helps answer this call. Specifically, findings from my study indicate factors such as organizational culture, beliefs about skills, and external influences that mitigate or amplify a feeling of tension between day-to-day organizational tasks and collaborative commitments.

Summary

In this chapter, I motivated the research, explained the need and purpose of the study, and presented significance for the VT PEERS project and through a broader lens. I also provided a brief overview of the NSF-funded project in which this research is situated, and this will be elaborated upon in the section “VT PEERS Study Context” in Chapter 3 to set the stage for case construction. I have argued that national calls for STEM workforce development considerations alongside increased demand for STEM content in schools puts overtaxed, underprepared, and under-resourced teachers and school systems in a precarious position. I have also suggested that strategic partnerships among school systems and industry may help address some of these concerns, but more research is needed to link collaboration in this context with the theoretical foundation for collaboration found in other fields. Ultimately, the goal of this research is to build an understanding of how an interorganizational collaboration in the K-12 STEM context develops through the first year to contribute to the literature in both collaboration and pre-college engineering education.
Chapter 2. Relevant Literature and Theoretical Underpinnings

Introduction

There are two goals I seek to address through this literature review. First, I will provide background on the current state of K-12 and engineering education including a discussion of engineering pedagogical content knowledge and national engineering learning standards as relevant to this investigation. Second, I will explore theoretical perspectives of collaboration and supplement this with examples from collaborative practice. This exploration does not take for granted a notion of an ideal partnership and an assumption of what that looks like. Instead it lays the groundwork for situating the collaboration as it emerges through the VT PEERS project. This review is both a widening and narrowing down. I will widen to explore the fundamental theories behind frameworks of collaboration and narrow to place these frameworks in context.

Goal 1: Provide background on K-12 engineering education. The context of this research is a program that brings engineering-focused activities to the public middle school science classroom. It becomes important to explore the current status of secondary engineering education in the United States to gain a better understanding of this context from both a practical and research perspective. Although it is easy to point to the national discourse around the need for more and better K-12 education in science, technology, engineering, and mathematics (STEM), it is more challenging to establish a clear understanding of the system in which these proposed changes will have to take place. In the K-12 engineering education section, I will review literature towards developing a basis of the educational context of my research. Although it may be beneficial to adopt a global perspective to education reform in discussing issues such as economic competitiveness (Sahlberg, 2006) or comparing foreign and domestic perspectives on teaching to gain new insight (Hiebert & Stigler, 2017), emphasizing the unique structure of U.S. education provides directly applicable mapping in which to situate the rest of my research.

The study of K-12 engineering education is still young compared to the breadth of literature on science and mathematics education. New fields are emerging that consider these disciplines together in an explicit and integrated way. For example, the field of integrated STEM (iSTEM) takes the initial idea of combining science, technology, engineering, and mathematics from the 1990s and considers explicit connections among the different disciplines (Sanders, 2013). This trend can be seen in education reform movements as well. The Next Generation
Science Standards (NGSS) combine what they call science and engineering practices, doing away with the separate designations of the engineering design process and the scientific method and opting for an integrated approach (NGSS Lead States, 2013). For these reasons, and because the VT PEERS project spans multiple disciplines, research involving STEM subject areas outside of engineering will be considered in this review.

**Goal 2: Explore collaboration theory and practice.** The second goal of this review is to explore theoretical perspectives of collaboration and supplement this with examples from collaborative practice to provide the framing for the future analysis of the collaboration data. In doing this, I will also examine the research that has formed the foundation of the frameworks used in analysis. Literature on collaboration is largely practically motivated and theory is still emerging. This research is primarily grounded in the theoretical work from Gray (1989) and Gray and Wood (1991) in behavioral science and Thomson, Perry, and Miller (2007) in public administration supplemented by supporting work in collaboration from adjacent fields of study (e.g., education and business). Although the original publication from Gray (1989) is from nearly three decades ago, the work continues to be used to support research on complex collaborations and thus it serves as truly foundational work. For example, in research on transnational higher education partnerships, Bordogna (2018) uses Gray (1989) to situate their work in the partnership literature. Similarly, Cloutier and Langley (2017) build on Gray’s perspective by exploring the moral purposes behind differing stakeholder motivations. Gray (1989) embarked on a robust exploration of public-private collaborations seemingly in response to the complex and interrelated problems becoming more and more prevalent at the time. This is no less true today as the VT PEERS project builds capacity to address the complex problems underlying broadening participation to rural students in engineering. Gray (1991) emphasizes that “no single theoretical perspective provides an adequate foundation for a general theory of collaboration” (p. 3). This is especially the case in the context of this research: an interorganizational relationship focused on STEM education in the K-12 context. The variety of groundwork completed towards developing theory in this space is important to review before bringing in this additional layer of context.
K-12 Engineering Education

Despite national calls prioritizing K-12 engineering education and workforce development, engineering is not a core academic subject, and it is often integrated into other subject areas. Knowledge about engineering and how to teach this unique interdisciplinary subject is unsurprisingly lacking in current educational practice. Overall, there is a misalignment between the national calls to action and the structure of the education system.

Types of content knowledge in teaching. It is an assumption in everyday conversations that the difficulty in teaching lies in the difficulty of the subject matter (e.g., the assumption that teaching fourth grade mathematics is inherently easier than teaching Algebra II in a high school because the material is more advanced). Yet, real expertise in teaching is more complicated than this assumption alone. To start, Shulman (1986) defines three types of content knowledge for teachers: “(a) subject matter content knowledge, (b) pedagogical content knowledge, and (c) curricular knowledge” (p. 9). Subject matter content knowledge is not just a teacher’s command over a set of facts in a discipline but also includes a deeper understanding of a discipline such as how it is organized, different perspectives on the same issue, and why certain topics are important. For example, a science teacher might understand well the theory of evolution and its tenets but should also be able to link how the geological evidence that the continents were once connected support the theory. Taking subject matter knowledge a step further, pedagogical content knowledge (PCK) is the knowledge of how best to teach the content including, for instance, ways of presenting the topic and an understanding of common misconceptions. For example, the same science teacher would need to be aware of the common misconception that individual organisms evolve (Gregory, 2009). Curricular knowledge refers to the third domain of teacher knowledge and is an understanding of the teaching tools at their disposal. The science teacher in these examples may have a command of general pedagogical strategies such as inquiry-based learning. All three of these come together to form teacher mastery of content knowledge.

Engineering pedagogical content knowledge: Teaching engineering in the K-12 classroom. Of the three categories of content knowledge, considerations of pedagogical content knowledge (PCK) are important when taking into account the challenges of bringing engineering to the K-12 classroom. According to Brophy, Klein, Portsmore, and Rogers (2008), this is particularly an issue for elementary and middle school teachers new to teaching about
When a teacher approaches teaching engineering design and what engineers do, the “answer is in the book” system breaks down (p. 381). Although engineering PCK has been studied at the level of college instruction, there is less of a precedent for it in the K-12 space. In the context of a first year engineering course, researchers studying instructors’ PCK found a disconnect between what the instructors expected in terms of student conceptions and actual student thinking (Viiri, 2003). Although instructors were able to reasonably predict student answers to questions, they were not able to predict their reasoning and were surprised by some of the student conceptions. In this way, PCK is a step beyond subject matter as knowledge of how best to teach the content including an understanding of common misconceptions (Shulman, 1986). Researchers specifically considering K-12 teachers’ engineering PCK found that knowing more about engineering did not necessarily translate into being able to teach it (Sun & Strobel, 2014). This has potentially interesting implications for studying a collaboration with the premise that an industry partner will help develop a teacher’s engineering PCK by sharing their engineering expertise. It is important to note that whether or not PCK has an impact on practice or learning are still major questions for researchers to uncover (Abell, 2008). Therefore, although PCK provides a useful structure to consider teachers’ perceptions of the impact of a collaboration on their professional practice, this investigation is not limited to this lens alone.

Researchers have also applied this concept of engineering pedagogical content knowledge in studying Albert Bandura’s notion of self-efficacy in K-5 teachers (Hammack & Ivey, 2017). They found low engineering and teacher self-efficacy in their sample of teachers and significant differences among demographic variables. For pre-service teachers, a positive relationship was found between science self-efficacy beliefs and science content knowledge (Menon & Sadler, 2016). The literature implies it may be intimidating to a teacher with low teaching engineering self-efficacy (Yoon, Evans, & Strobel, 2014) to work with an engineering expert, even if the goal is to increase their content knowledge, especially if the term expert is actually used to describe the external person in practice.

**Engineering learning standards.** In talking about PCK, something that is unclear is what the content knowledge that we are expecting teachers to master looks like in K-12 education. As the discussion shifts towards teachers, it becomes important to note that in many societies outside the U.S., teachers enjoy more respect and status (Dolton & Marcenaro-
Gutierrez, 2013). In 1972, Cogan wrote that a teacher should not be “treated as a person being rescued from ineptitude, saved from incompetence, or supported in [their] stumblings” (p. 21, as cited in Marzano, Frontier, & Livingston, 2011). It is easy to point out research on shortcomings that ultimately serve to vilify the teachers for not doing enough or teacher educators for not providing adequate training, but acknowledging strengths and building on what they do have is also important. This is especially true in consideration of research on collaborative processes that include a dimension of leveraging complimentary inputs.

**Learning standards in the United States.** Public education in the United States is largely standards driven. Common national learning standards and standardized testing are most associated with No Child Left Behind (NCLB), but they have a history that stretches back decades earlier (Fletcher, 2009). The act is part of a series of initiatives for federal oversight of schools dating back to the Johnson Administration. Its most recent iteration, the Every Student Succeeds Act, maintains the accountability measures of NCLB but allows states some flexibility in meeting the requirements as they develop their own comprehensive improvement plans (U.S. Department of Education, 2017). There is no shortage of research on the negative impact of the No Child Left Behind Act and the associated increase in state mandated standardized testing as a performance indicator for schools. One of the biggest complaints is that only certain subject areas are assessed. Some researchers argue that by focusing assessment on math and reading, it naturally incentivizes schools to redirect efforts and resources from other subjects such as social studies or technology education (Maranto, 2015; Pederson, 2007). Pederson (2007) in particular found that results from a survey study of state assessment directors between 2001 and 2005 showed that there was a reduction of resources, including time, to non-assessed subjects. This was a comprehensive review of the entire country after the enactment of NCLB. This background on standardized testing was provided to set the stage for the next major development in national learning standards: engineering guidelines through the Next Generation Science Standards.

**The Next Generation Science Standards.** Some states have adopted their own engineering standards, but there are also national learning standards for engineering outside of the official federal structures. The Next Generation Science Standards represent a turning point in nation-wide learning standards. Before the NGSS, only six states had explicit engineering standards (Carr et al., 2012). Now eighteen states and Washington DC have officially adopted
the standards (Heitin, 2016). For the first time, multiple states have collaborated to create engineering learning standards for elementary and secondary students. Because the NGSS are a recent addition to the K-12 landscape, research around the engineering standards focuses primarily on studies of perceptions on teacher preparedness and professional development experiences for teachers new to the standards. Additionally, although the 2013 release of the final draft of the NGSS was met with much fanfare, some researchers took the opportunity to critique the NGSS in terms of quality of the engineering-aligned lessons produced in addition to considerations of equity and access which will be outlined in the following sections.

The VT PEERS project classroom intervention activities are aligned with NGSS engineering standards. In many ways, this collaboration represents professional development for teachers in engineering and the NGSS. Research on professional development and the NGSS can enlighten us to the current state of school preparedness to bring engineering to the classroom. For example, researchers considered elementary teachers at two schools and their implementation of science and engineering units in conjunction with a subcontracted professional development experience (Biggers, Haefner, & Bell, 2016). Through analysis of videotapes of the lessons, findings revealed a major lack of integration of science and engineering and poor representation of the NGSS. They categorized factors related to adapting the Engineering is Elementary (Museum of Science Boston, 2016) lessons into those beyond and those within teacher decision making and control. Biggers et al. (2016) found the factors beyond teacher control to include district choice of units, the professional development model used, and kit rental logistics. Within the control of the teachers were missed or underutilized opportunities for connections, but this could be considered due to the setup of the professional development experience. In another case study of two elementary schools, researchers considered the potential for a sustained effect of NGSS professional development for elementary school teachers. Teachers participated in summer professional development and then implemented engineering lessons in their classrooms. Again, an Engineering is Elementary (Museum of Science Boston, 2016) unit was used. Some interesting effects to sustained implementation included high level of support in one school versus challenges to integration posed by a departmentalized structure of the second school (Douglas, Rynearson, Yoon, & Diefes-Dux, 2016). This is consistent with the discussion of factors out of a teachers’ control discussed in Biggers et al. (2016). Interestingly, Douglas et al. (2016) noted a limitation of their study is that there is limited research about what is an
appropriate learning outcome for elementary engineering. If we are considering the VT PEERS collaboration as a professional development experience for teachers, noting these limitations from the literature helps contextualize participant responses.

Standing apart from the other research on elementary NGSS engineering professional development is the longitudinal study by Nadelson and Callahan (2014) because it considers the administrative perspective on professional development. The principals’ interpretations of their faculties’ experience was the primary focus of the investigation. The most salient finding was that principals perceived the summer experience altered teaching culture and action (Nadelson & Callahan, 2014). Overall, the researchers painted a significantly sunnier picture about elementary professional development in NGSS engineering than did their contemporaries. In this study, I consider the different perspectives of administrators and teachers in a collaboration and this literature supports the notion that administrators may see additional benefits beyond what is actualized by their teaching staff.

Up until now, the professional development research around engineering and the NGSS that I have reviewed has been focused on the elementary grade level. Although elementary is surprisingly an emphasis in the literature, professional development for secondary teachers is a focus of the research as well. Reviewing both makes sense for the background of a study focused on the middle school grade levels which often fall in between elementary and secondary. In a national study of middle and high school teachers in 38 states, Haag and Megowan (2015) received survey responses that indicated engineering professional development was needed the most for preparation to implement the NGSS. Lesseig, Nelson, Slavit, and Seidel (2016) take a unique look at teacher preparation in NGSS engineering by describing and analyzing the professional development model itself. Like Turner (2015), they sought to discover barriers to implementation, but instead of looking at teacher perceptions, they studied teacher professional development experiences using surveys, observations, field notes, and also artifacts to determine what participants found valuable or difficult. One challenge noted is that teachers had problems integrating the engineering design challenges into their existing curriculum.

Critiques of the NGSS. As I discuss the NGSS and its implications for this project, some literature is notably different from the research being done on teacher readiness and implementation in that the authors evaluate the standards themselves. Cunningham and Carlsen (2014) provided a table comparing science and engineering based on the interpretations from the
National Research Council that led to the development of the NGSS. They cite dangers of conflating science and engineering in standards for teachers unfamiliar with the distinctions between them. They call for integration of engineering into pre-service teacher education which mirror the calls for better pre- and in-service preparation noted in Chapter 1.

While Cunningham and Carlsen (2014) critique the NGSS for the risk of conflation of engineering and science, Moore, Tank, Glancy, and Kersten (2015) critique the content of the engineering standards themselves. They evaluate the engineering standards considering The Framework for Quality K-12 Engineering Education developed iteratively by educational researchers from 2008 through 2014. They found that the engineering-related standards were mostly consistently distributed across the grade levels with a lower amount for grades 3 through 5. According to their evaluation, the performance expectations do not meet the criteria for “comprehensive K-12 engineering education” (p. 309). Ethics, communication, and professional skills are among the areas lacking in the NGSS engineering standards.

**Equity and Access.** While the researchers discussed above critique the NGSS for its content-related shortcomings, others adopt critical viewpoints about the social implications of the standards. Research considers the NGSS and equity in access as well as assumptions of normative practice in educational policy. This background becomes important in an investigation of rural school divisions. Alberto Rodriguez (2015) considered the social implications of swiftly adopting an education reform such as the NGSS. Rodriguez (2015) offered a similar critique of the 1996 National Science Education Standards and now evaluates the NRC Framework and the NGSS. He offers that the Framework and NGSS were significant improvements over previous national standards in that they to some degree acknowledge issues of equity, use teacher-centered case studies, employ a “less is more” ideology, promote learning as a progression, and spotlight engineering (p. 1035). Nevertheless, Rodriguez (2015) contemplated the true impact on student achievement of the standards and noted insignificant improvements particularly among ethnic groups. He provided factors for engagement, equity, and diversity and suggested a “culturally diverse task force” to embed these factors in the standards (p. 1042). Rodriguez also called into question who is considered an expert in developing these standards. In Learning to Improve: How America’s Schools Can Get Better at Getting Better, Bryk, Gomez, Grunow, and LeMahieu (2015) describe education reform as a form of design and their overall message is that the users (i.e., the teachers) should be involved in the design. Although not as critical, other research
considered the implications of the NGSS as education reform in American society and concludes “economic competitiveness” and “individual success” are the reasons the NGSS suggests the U.S. should adopt the standards and explained that this is also a good argument for why “disadvantaged” groups should do science and engineering (Cafarella, O’Connor, & McWilliams, 2016). Rodriquez (2015) essentially takes that sentiment and offers strong arguments as to why those disadvantaged are still such under the current version of the NGSS. When engaging with rural populations, considering who the NGSS excludes in its design and implementation becomes important.

Summary. There are two major takeaways from the discussion of the literature surrounding K-12 engineering education. The first is that of the three categories of content knowledge, considerations of PCK are most important to consider in bringing engineering into the secondary classroom. Pedagogical content knowledge in engineering means that teachers will be able to merge the “book” knowledge of engineering with their toolkit of pedagogical strategies and be reactive in the classroom. Where this content knowledge comes from, however, is also important. The NGSS and surrounding K-12 engineering education infrastructure were explored here as the major source of engineering content knowledge that teachers are accessing through the classroom. The second salient point is that teachers are underprepared and under-resourced to successfully bridge this content with their current teaching practices. Notably, in consideration of an investigation of collaboration that considers multiple educational stakeholders, teachers and principals may have different perspectives on the outcomes of NGSS professional development. In the same vein, it was important to consider critiques of the engineering standards, particularly with regard to equity and access, for a study in the rural context.

Organization Theory Supporting Collaboration Frameworks

Now that I have reviewed background on engineering in K-12 education (Goal 1), the remainder of this chapter will focus on theoretical perspectives of collaboration and contextualizing them for this study (Goal 2). Before defining the framework of collaboration used in the analysis detailed in Chapter 3 (Thomson et al., 2007), I will briefly provide the organization theory underlying the research that forms part of the basis of this framework. Recall from the introduction that this research is partially grounded in the theoretical perspective
provided by Gray (1989) and supplemented by additional scholarship around collaboration and partnership. This additional scholarship (i.e., Thomson et al., 2007; Thomson & Perry, 2006) bases much of their work in Gray (1989). Gray (1989) presents work towards “a theory of collaboration as an emergent interorganization process” in contrast to previous work that focuses on transactions between organizations or structural aspects of the relationship (p. 227). For example, Gray (1989) cites Fombrun (1986) who recasts an interpretation of three levels of structure involved in interorganizational relationships. In grounding a theory of collaboration, Gray (1989) draws on negotiated order theory from a number of scholars in the area (e.g., Day & Day, 1977; Strauss, 1978) which emphasizes the emergent quality of organizational factors and that order is collectively achieved through conflict as much as consensus. Gray (1989) takes the following quote from Day and Day (1977).

The negotiated order theory downplays the notion of organizations as fixed, rather rigid systems which are highly constrained by strict rules, regulations, goals, and hierarchical chains of command. Instead, it emphasizes the fluid, continuously emerging qualities of the organization, the changing web of interactions woven among its members, and it suggests that order is something at which the members of the organization must constantly work. Consequently, conflict and change are just as much a part of organizational life as consensus and stability. Organizations are thus viewed as complex and highly fragile social constructions of reality which are subject to the numerous temporal, spatial, and situational events occurring both internally and externally (Day & Day, 1977, p.132 as cited by Gray, 1989).

The argument for interorganizational collaboration as a negotiated order hinges on several key points from Gray (1989). Using the language from the author, these major foci are: collectively devised strategies for responding to environmental turbulence, collaboration as a temporary and emergent organization form, collaboration as quasi-institutional mechanism for accommodating differing organizational interests, and collaborations as vehicles for action learning. Each will be explored in turn.

**Collectively devised strategies for responding to environmental turbulence.** Stakeholders jointly develop strategies to deal with external environmental factors outside of their control. Through the review on K-12 engineering education, I highlighted environmental
turbulence within the education system in particular. As problems become more interconnected, stakeholders from different organizations must come together in shared problem solving. In the VT PEERS project there are stakeholders from the university, the K-12 school systems, and the engineering industry partner. The university may be interested in broadening participation in engineering to rural students. The school system may want to improve their curriculum, student engagement in the classroom, or help students envision a wide variety of careers for themselves. The industry partner may be motivated by altruism but more likely that they are sowing the seeds for establishing successful future employees local to their community. All these organizations depend on one another and collaborating offers advantages that going it alone would not.

**Collaboration as a temporary and emergent organization form.** Interorganizational collaborations are what the author calls “dynamic negotiations” and have a character that is “imprecise, emergent, exploratory, developmental” (p. 230). This key point emphasizes the notion that collaboration is a process and collaborations evolve on a spectrum as will be discussed and supported in adjacent literature. The collaboration can become more organized over time as stakeholders proceed from problem-setting through direction-setting and implementing.

**Collaboration as quasi-institutional mechanism for accommodating differing organizational interests.** As these collaborations form in rule and agreement, they become something more than the sum of their parts, an entity in their own right that is still developing. They have the capacity to change existing structure within their component organizations. For example, a partnership with an engineering firm and a school may result in institutionalized structure for employees to regularly engage with the school system in the future.

**Collaborations as vehicles for action learning.** Different organizations frame their problems from their own unique perspective and may inadvertently constrain their solutions. Organizations may assume conflicting interests and can discover latent shared interests through the process of collaboration. Negotiated order is created as the organizations develop a shared problem formulation.

**Beyond theories of negotiated order.** Although this initial interpretation is based in the organization theories of negotiated order, several years later, Gray (1991) explores other theoretical perspectives that ground a theory of collaboration. These include resource dependence, corporate social performance/institutional economics, strategic management/social
ecology, microeconomics, and political theory. Research on collaboration that has applied Gray (1989) has also used more than one of these theoretical perspectives in combination (e.g., Guo & Acar, 2005). Gray (1991) concludes that “none of these theories offers a comprehensive model of collaboration” (p. 10). Some of these theoretical perspectives emphasize collaborative preconditions (e.g., resource dependence) while others emphasize process (e.g., political and negotiated order). One notable comment from this exploration is the question posed by considering a political perspective: “who has access to power and resources” and “who does and does not benefit” (Gray, 1991, p. 8). Power is an important dynamic in any relationship and interorganizational partnerships are no different. A partnership includes all stakeholders necessary to achieve the goals, not just those that can most easily work together (Kernaghan, 1993). In some of the interorganizational relationships discussed in this chapter, it can be inferred that one party has significantly more leverage than the other. For example, university students in an engineering themed service-learning course seeking to work with a community organization representing a group traditionally underrepresented in engineering poses inherent difficulties related to power. These power differences cannot be erased even through sharing control in a partnership, but power sharing must still be emphasized in interorganizational interactions. This notion is most clearly understood through the idea that a partnership allows for shared decision-making power (Kernaghan, 1993). In considering healthcare sectors and education in nursing and midwifery, Casey (2007) presents the idea from their past work that equality between partners is not possible, but shared decision-making is. Moreover, power is a common theme (both implicit and explicit) in the negotiated order lenses reviewed by Day and Day (1977).

**Defining Collaboration as an Emergent Process**

“Collaboration is not an ‘either or’”; it is a complex, dynamic process (Thomson et al., 2007, p. 25). The literature may present an ideal notion of partnership, but interorganizational collaboration in practice rarely occurs this way. For example, there is one interesting case involving a partnership between community organization, educators, and what they call resource agencies to bring wildlife education programs to students (Monroe et al., 2016). Monroe et al. (2016) discussed implementation using different models of school and community partnership ranging from the educator making connections to community issues without any interaction with
a community partner to full cooperation between a community partner and educator to engage youth in the classroom (Uzzell, 1999). This provides a useful way to analyze programs and their progress along the way during implementation. It is clear that collaboration in practice is best interpreted on a spectrum. Using the language of Gray (1989), this is better conceptualized as collaboration as an emergent process that develops along a continuum. There is a precedent for considering types of collaboration from consulting to cooperative work in the field of education (e.g. Fishbaugh, 1997) and detail about how this looks from the collaboration literature at large will be discussed below from other fields.

In explaining collaboration, Gray (1989) uses the phrasing “problem domain” (Trist, 1983) to mean “the way a problem is conceptualized by the stakeholders” (Gray, 1989, p. 5). Collaborative problems as Gray (1989) defines them are ill-defined and complex, have a variety of stakeholder interest and who the stakeholders are might not be obvious or predefined, and are problems for which other methods have fallen short of results. The process of collaborating is as complex as the problems it seeks to solve. Gray (1989) conceptualizes this as a process that starts with a problem setting phase of initial interactions, a direction setting phase of more explicit structural considerations, and an implementation phase. This is not unlike the way Thomas et al. (2010) conceptualizes interorganizational relationships on what they call the partnership continuum. What is unique about this conceptualization is that rather than depicting a spectrum of relationships from some type of partial to full partnership, Thomas et al. (2010) shows a continuum of interpersonal relationships from individuals interacting to entire organizations working together. This is arguably the most realistic trajectory for a partnership and how partnerships are established. After all, organizations are made up of individuals making decisions. The continuum starts with unplanned contacts between individuals at different organizations. For example, a researcher might have been a former teacher at a school and was involved in a casual interaction with a former colleague about issues facing the school system. It moves to slightly more formal links between individuals or a subunit of an organization. To continue the same example, the former colleague and the new researcher might agree to start an action research project together. The continuum then moves to a more formal partnership that might encompass some of the values discussed later in this chapter onto a strategic partnership emphasizing all the principles of mutuality.
While Thomas et al. (2010) presents a partnership continuum in the education space, the notion that collaborations develop over time is appreciated in other fields as well. Thomas et al. (2010) is similar to the typology of partnerships presented by Kernaghan (1993) in the public administration space that can be placed along a continuum: collaborative, operational, contributory, consultative, and phony. These types of partnerships have been considered in multiple contexts to better understand interorganizational relationships. For example, Kernaghan (1993) has been utilized in the study of relationships between healthcare sectors and education in nursing and midwifery (Casey, 2007). The first type of partnership he presents is called an operational partnership. Operational partnerships are more about simply “working together” rather than sharing decision-making control or power (Kernaghan, 1993, p. 63). Contributory partnerships involve one organization providing financial or other support to another and consultative partnership involves only advice giving on the side of one party. What sets these apart is mainly that they do not emphasize the power sharing of the collaborative partnership. However, these relationships are not necessarily lesser in the plain meaning of the word; they are valuable in their own right. An organization such as a company providing funding to a community organization to bring about a change is not a bad thing, even though it is not a collaborative partnership on the far end of this spectrum. But on the other end of the spectrum, the authors present the phony partnership. Unlike the others, this is a partnership that is not a partnership at all because it represents a one-sided relationship in which one stakeholder benefits at the expense of others. Kernaghan (1993) puts it simply when he states that for this type of partnership “the likely result is disempowerment” (p. 65). Similarly, Thomson and Perry (2006) note that collaborating for individual goals alone is “likely to result in failure given the complexity of the collaboration process” (p. 28). This connects well to the idea of shared power discussed below. If organizations are not willing to acknowledge the systemic issues related to disparity in power, particularly in public-private sector relationships, then the relationship may not be able to expand out of this superficial zone. Seitanidi and Ryan (2007) also discuss partnerships between not-for-profits and corporations on a spectrum of philanthropy to partnership. They acknowledge that the natural tendency is for the relationship to favor the corporation as a for-profit organization unless the not-for-profit makes efforts towards staking their claim of shared benefits. This view is perhaps pessimistic but also realistic given the motivation of corporations to make money. The implication is that some of the contributions that
the not-for-profit might make to the corporation that also might influence profit positively are not as clear as the direct profit motive. These might include the contributions that a corporation might enjoy from a partnership such as increased employee morale (Googins & Rochlin, 2000), increased employee productivity, and therefore more profit.

Gray (1989) emphasizes that collaboration is a process and the partnerships at the far end of the spectrum may not be the starting point of an interorganizational relationship. For example, it may be perfectly reasonable to think about the collaboration in terms of a consulting relationship and later establish joint goals. What is nice about the continuums such as those described in Thomas et al. (2010) is that they provide a more realistic metric for investigating development of strategic partnership. Thomas et al. (2010) does not deny the fact that partnerships often develop from a few individuals with an idea or one party approaching another with a proposed project requiring their help. Practically, these spectrums also provide a trajectory to scaffold a relationship towards long-term collaboration.

A Framework of Collaboration

Although the work from Gray (1989, 1991) is important for characterizing the organization theory underlying collaboration research, Thomson et al. (2007) provides a useful operationalization of collaboration theoretical constructs to guide the empirical research conducted. However, because Thomson et al. (2007) is rooted in public administration, additional literature from education and background on industry considerations are necessary to supplement the framework to be most appropriate for this investigation. Still, public administration as a field is not totally alien to the context of the VT PEERS project. Much like the engineering education context in which this research takes place, public administration is an interdisciplinary field that draws theory from other fields of study such as sociology, psychology, economics, and management.

From literature on collaboration and their own empirical work, Thomson et al. (2007) put forth the following definition of collaboration.

Collaboration is a process in which autonomous or semi-autonomous actors interact through formal and informal negotiation, jointly creating rules and structures governing their relationships and ways to act or decide on the issues that brought them together; it is a process involving shared norms and mutually beneficial interactions (p. 25).
Other researchers such as Mattessich, Murray-Close, and Monse (2001) also synthesized a large amount of literature on collaborative efforts from a variety of disciplines and their definition of collaboration presents similarly to the one provided by Thomson et al. (2007). Both works are in part based in Gray (1989) and echoes of Gray’s work can be seen across definitions in the literature. What stands out the most in contrast to Gray’s definition is the mention of shared norms by Thomson et al. (2007). It will become clear in the collaborative dimensions presented here that this is an emphasis on trust and reciprocal actions.

The five dimensions are presented in Thomson et al. (2007) but described in more detail in the early work from Thomson and Perry (2006). Thomson and Perry (2006) support their claims with a robust selection of literature and additional literature is provided here to support and recontextualize the dimensions outside of the public administrative lens from which they originated. For example, it may be important to make connections from these dimensions to the business and education world as these are the types of organizations involved in the VT PEERS project. The following dimensions of collaboration supporting the analysis described in Chapter 3 are: governance, administration, organizational autonomy, mutuality, and norms of trust and reciprocity.

Governance. Governance refers to the idea that participants in a collaboration must cooperatively develop structures and rules related to decision making and other constraints related to collective action. Central to partnership is the idea of shared vision and goals to support that vision. Partners have joint goals that they share the responsibility of achieving (Kernaghan, 1993). Considering strategic partnerships in this business sphere, Henderson (1990) interviewed executives involved in partnership. Participant responses echoed this idea of shared goals but participants discussed it in terms of commitment to the collaboration. For their business partnerships, joint planning how to achieve these goals was considered important. Similar evidence for the importance of shared goal development presents itself in the education-related literature. In developing shared vision, participants in collaboration noted that considering limitations was involved in actualizing the vision (Thomas et al., 2010). Establishing limitations to what is possible to achieve is a challenge worth noting as a precondition to collaboration. Because VT PEERS is externally funded, some stakeholders might not have the chance to participate in the initial goal setting process. This research implies that this relationship could
develop into a partnership if the other stakeholders help bring the goals down to earth and consider limitations.

As another example of the governance dimension in action, in designing school-university partnerships that are sustainable, Gardner (2011) identified collaborative dimensions that should be considered including planning, decision-making, implementation, and evaluation. A major takeaway for the reader was that sustainability was not just about money but was about the goal sharing aspect of collaboration. If all parties are committed to jointly developed goals, there is an inherent motivation to continue the work.

**Administration.** The dimension of administration considers the difficulty of transitioning from governance to taking actions towards meeting goals when independently operating parties come together to collaborate. Considerations of clear communication practices, roles, and responsibilities replace traditional hierarchical administrative systems. In an interorganizational relationship focused on K-12 STEM education, partners may take on roles they never previously imagined (e.g., an engineer leading something in the classroom or a teacher having an interpretation of an engineering concept).

To illustrate further, a partnership between a university graduate student program and high school science and math teachers has implications related to sustainability. The program is called the Graduate Student-University-School Collaborative (GraSUS) (Dolan & Tanner, 2005). From the researchers’ perspective, “the one-way flow of activities from the university to middle and high school classrooms created little reason for teachers to take ownership” (p. 29) or use the activities after the program was over. This is the crux of the issue that the higher education partner faced in establishing a dimension of sustainability in their partnership arrangement with the schools. This is also a challenge relevant to the VT PEERS project. The researchers’ solution was to ask that the teachers originate the ideas, a shift in roles, instead of the faculty and students that initiated the program (Dolan & Tanner, 2005). The teachers were then able to identify areas in their curriculum that most needed the improvement provided by partnering, and interactions between all partners increased.

**Organizational Autonomy.** The dimension of organizational autonomy is the pull between “organizational self-interest” and “collaborative interest” of the group (Thomson et al., 2007, p. 26). In a cross-sector partnership involving corporations, issues can arise if social goals conflict with economic self-interests (Stadtler, 2011). One might ask how a corporation could
possibly benefit from a community partnership that does not have a direct impact on the product they produce or service they provide. In a program involving student design projects, it was the media attention brought by the endeavor that supplied the mutual benefits in the relationship (Radinsky et al., 2001). Established up front, a shared goal in a public-private partnership between a corporation and a school could be to raise awareness of an issue such as technological literacy. The school might benefit from the presence in the classroom of an organization that applies digital technology to achieve their business goals. The shared benefit for the corporation could be to establish their corporate identity with the issue and potentially attract new employees (Stadtler, 2011).

Aligning their work well with the idea of the pull between collaborative- and self-interest, Colbry, Hurwitz, & Adair (2014) identified two major aspects of collaboration on a team: individual first and team first. The themes under the category of individual first include turn-taking, observing or doing, and status seeking while the themes under the category of team first are building group cohesion, influencing others, and organizing work. A brief description of each of these themes are provided here.

Individual First:

- **Turn-taking:** the formal and informal acknowledgements of collaborator participation. These encompass personally and socially motivated choices to participate, lead, or follow.
- **Observing or doing:** how collaborators act on a spectrum from observing how others act to having a hand in all aspects of activity, and the personal, social, and/or environmental factors involved.
- **Status seeking:** the extent to which collaborators evaluate their actions and contributions in terms of how they will be viewed inside and outside the team.

Team First:

- **Building group cohesion:** the leader and group responsibilities adopted towards achieving group effectiveness.
- **Influencing others:** how team members influence each other’s actions towards reorienting to the purpose of collaboration.
- **Organizing work:** how teams organize work with/without leader or manager oversight.
**Mutuality.** The dimension of mutuality addresses this tension of different or shared interests as a necessary component of building “beneficial interdependencies” (Thomson et al., 2007, p. 27). As previously mentioned, these dimensions were established for public administration, but the notion of shared benefits crosses disciplines. Specifically, it is not new to partnerships in the business world. Considering strategic partnerships in the business sphere, Henderson (1990) interviewed executives involved in partnership relationships. The notion that shared benefits, explicitly defined, were necessary for partnership was common in participant responses. In an interorganizational relationship involving a private business and a public entity this may be particularly important to consider. If only the public entity benefits than the relationship may look more like charity than partnership. If only the business benefits, that might amount to exploitation. Between these extremes is an interorganizational relationship with shared benefits.

In the education sector, interviewing staff at schools and colleges about forming links between these organizations, researchers found participant responses that also aligned with this idea of mutual benefits (Thomas et al., 2010). In fact, this was the most frequent participant response. No one wants to waste their time or money, and these are both resources critical to conserve for the success of the organization in both business and education. This will be discussed further in the section considering the industry perspective in more detail. To give a better idea of how this looks in practice, in a school-industry partnership focused on the idea of mutual benefits, industry benefited from the media attention brought by student design projects and students benefited from industry support (Radinsky et al., 2001). However, the intention was for the product of the students’ designs to benefit the industry partner. This was an important finding because a secondary product of the collaboration, the media attention, was not necessarily intended to benefit the industry partner. Predicting what these mutual benefits might be could be a challenge for an interorganizational relationship for which there is not a great deal of precedent. A partnership among a university, a Latino community group, and public schools, may have combatted this by articulating a clear statement as to the shared benefits in the relationship (Oberg De La Garza & Moreno Kuri, 2014). The authors argue that the community center united their cultural expertise with the teachers’ pedagogical expertise and that this helped the teachers become better teachers and leaders and helped their Latino students achieve.
**Norms of Trust and Reciprocity.** The last dimension considers that success concerning the dimension of mutuality is impossible without trust and shared responsibility. Trust is another dynamic identified in the previously mentioned literature on partnership (Kernaghan, 1993). In the example from the partnership among a university, Latino community group, and public schools, one major conclusion centered around the idea of trust as connected to power through democracy and social justice (Oberg De La Garza & Moreno Kuri, 2014).

Sharing responsibility is not just sharing responsibility for decision-making, but also for resources (Kernaghan, 1993) such as time, knowledge, and other capital investments in the relationship. Googins and Rochlin (2000) discussed the underlying assumption of cross-sector partnership is that each party contributes the resources for which they are uniquely suited to provide. For example, they suggested that in a corporate-community partnership, a corporation might contribute resources such as money or volunteers, and the community might contribute services such as service learning opportunities for employees or help develop something as with the student design projects described in Radinsky et al. (2001). As a real-world example, in a collaboration of math and science teachers and content experts from higher education, the goal was for teachers to bring their instructional expertise and for university faculty to contribute content expertise to bring the math and science content to the classroom (Hamos et al., 2009).

**Unique Factors to Consider for Industry and the VT PEERS Project**

In view of the educational and collaborative factors explored thus far, a unique aspect of this research is the inclusion of working engineers in industry in the K-12 classroom. The purpose of this section is to discuss some unique factors and examples from the literature that are relevant given this context. Even though there is evidence that industry agrees getting involved in K-12 is valuable, participation by industry in these sorts of activities is not prevalent (Bruning, 2003). To this end, there are several potential challenges and considerations for industry in these sorts of collaborations that might help consider this question in the context of my research.

**Conflicts of interest.** For example, Stadler (2011) stresses the importance of managers considering potential conflicts of interest between business and social goals and establishing links between them whenever possible. It is hard to ignore the obvious conflicts that might arise when corporations agree to provide some of their resources such as people, money, or equipment to a K-12 school. Moreover, the dimensions of Thomson et al. (2007) demand that these factors
of conflict be considered explicitly in an analysis of an interorganizational collaboration. An industry involved in a collaboration such as the VT PEERS project would be asked to provide employees to spend their time involved in collaborative activities. It would be great if these activities could somehow align with business goals, but this may not be the case. The notion of labor modeling in business is useful for conceptualizing this. It is about balancing the necessary supply of skilled workers with the demand (Thompson, 1997). Collaborating with K-12 schools creates additional complications related to ensuring the company has enough of an employee’s time to still complete their economic objectives or deliver their services. Thomson and Perry (2006) use Huxham's (1996) interpretation of the time dimension that distinguishes time spent on progressing collaborative actions versus time spent on logistics or lesser priorities. The main takeaway is that time should be considered explicitly as a resource in a partnership. Other evidence in this section would suggest that this notion would be important to managers as well as schools.

As an illustration of some potential complications in action, Rogers and Cejka (2006) discuss preliminary findings from an investigation of the impact of engineering industry volunteers in K-12 classrooms. The program under investigation was implemented by National Instruments and placed hundreds of engineers in K-12 schools in Texas. The idea was to bring together teacher pedagogical knowledge and engineering content knowledge in the classroom. The authors state that teachers could bring their pedagogical knowledge and the engineering volunteers, called classroom mentors, could bring their content knowledge in engineering. This was a preliminary study of teachers and engineering volunteers’ perceptions of the experience. The exact timeline is unclear, but some of the volunteers and teachers worked together for multiple years. Although the majority of the reported results are interpreted positively, there are some challenges noted that are relevant. A potential limitation not addressed in the paper is that participating teachers and engineering volunteers self-selected to respond to the survey. Few negative comments were reported from the industry volunteers but one particular comment stood out: volunteers were unaware with how their management perceived the collaboration. For instance, a participant was particularly concerned that time spent away from his desk working in the schools was perceived as “slacking off” (Rogers & Cejka, 2006, p. 12). This was true even though this is a well-established program that provided training for industry partners in
pedagogy. If employees can feel this way after participating in a collaboration for years, there are severe implications for a new collaboration between a corporation and school.

**Favorable factors.** Although there was no literature from my search that explicitly suggested that a specific engineering industry might be more willing to participate in a collaboration with schools, it is reasonable to assume that an industry that already has a robust system for managing these sorts of collaborations would have an advantage over smaller companies with little or underdeveloped outreach activities. Specifically, the more established industry-based programs or companies with a precedent for collaborating with schools would be able to more easily manage their employees’ time and be able to justify the use of resources. For example, at the American Society of Engineering Education Conference, Boncek (2013) presented about a partnership involving his company, Raytheon, and the New England Patriots to promote STEM in secondary education. A quick search of Raytheon’s website reveals that they are already a sponsor of multiple informal STEM education organizations and a participant in educational research ("Raytheon: Education," 2017). Still, a smaller business reliant on local or regional customers may be motivated to interact with their community as a form of advertising. In view of this, they may want to build positive associations with their brand and establish their corporate identity with a social issue to potentially attract new employees (Stadler, 2011).

**Incentives.** Incentives for workers to contribute to a collaboration with schools have been previously discussed implicitly. Literature on organizational incentives identifies three main types of incentive systems: material, solidary, and purposive from the prominent work of Clark and Wilson (1961). As I explore the collaboration in the VT PEERS project, it may become useful to understand employee motivations from an incentive perspective. Material incentives are exactly what they sound like, concrete rewards such as money. Solidary incentives are all those non-physical benefits that might be reaped such as greater comradery from socializing with peers. Lastly, purposive incentives center around broader organizational goals that employees may rally around. In a collaboration, this is essentially the shared stakeholder conceptualization of the problem domain described by Gray (1989).

**Logistical considerations.** There are also practical concerns related to large distances, or even a distance of just a few hours, between an industry partner and a school. Corporations may not want to pay for their employees to travel and likewise teachers can hardly be asked to spend their own money and time driving long hours. Stress from difficulties commuting to work,
specifically related to traffic, may extend to the workplace once you arrive (Hennessy, 2008). When we add to this fact that teachers already work long hours (Scholastic and the Bill and Melinda Gates Foundation, 2012) and the rural context, it becomes evident that distance most likely presents a barrier to successful collaborations between schools and engineers.

Logistical concerns that come with the territory of being in a school system means that other stakeholders must rely heavily on the school to provide guidance for managing time as a resource. Thomas et al. (2010) have developed a tool for schools and higher education institutions looking to develop strategic partnerships. One segment of questions prompts the partners to consider multiple dimensions of implementation. These include considerations of how responsibility for implementation will be shared (e.g., making sure there are enough people available). There is also the notion of developing a shared approach but acknowledging the differences in organizational practices. This would be particularly important in a collaboration involving school systems and corporations which have institutional values that vary greatly. Notably, Thomas et al. (2010) also prompt users of this tool to consider how they will address the issue of distance. In jointly developing a plan to address implementation concerns, schools and other organizations should explicitly consider how they will communicate to effectively implement their programming.

**Examples of education-industry collaborations.** Although examples of collaborations have been discussed throughout, I will bring to the forefront some specific examples of schools and engineers collaborating and the implications. In a collaboration that brought graduate life science students into a classroom, one challenge noted was that some graduate students were not able to judge the appropriate level of complexity in pitching the material in class (Laursen, Liston, Thiry, & Graf, 2007). Recognizing this issue, faculty who created a collaboration involving biomedical engineering students in middle schools set as a goal that the undergraduate students would have a better understanding of how to design instructional material in agreement with the science of learning (Olds, 2004). However, in this case the partnership itself was supposed to yield this result, and it is not entirely clear if the researchers assessed the undergraduate students teaching ability.

As another example, Pawloski, Standridge, and Plotkowski (2011) described engineering college as a bridge in a collaboration with industry and K-12 schools. Their assessment was primarily on student-related outcomes, but the structure of their collaboration was such that a
university faculty member regularly contacted the other involved parties. In this way, a university mediator, preferably one with educational expertise, could potentially help assess engineers and also guide them in conveying their knowledge. As an example of something akin to this in practice, through a program involving engineering industry in K-12 classrooms, industry volunteers received some training in pedagogy and classroom management before going into the classroom (Rogers & Cejka, 2006). It is clear that challenges related to considering engineers’ capacity to teach both teachers and students is a very real shortcoming of bringing this type of partner into the classroom.

**Implications of a public-private partnership.** Lastly, the collaboration under investigation in this study can be thought of as a public-private partnership. Gray (1989) defines public-private partnerships as collaborations that combine public and private resources towards developing solutions for a community-level problem. Stephenson (1991) points to two major conceptualizations of public-private partnerships. Those that are driven by a set of predefined agreements among multiple organizations and those that are within single organizations with both public and private actors (p. 111). The VT PEERS project seems to fall somewhere in between these two conceptions. While the required participation from the collaborating parties is limited to the three-year scope, in design the project is positioned to continue beyond as something greater than the initial agreements that bound it.

**Chapter Overview**

Through this literature review, I met to two main goals. The first was to establish background on history and current status of K-12 engineering education. This is important because the context of my research is the VT PEERS program in which teachers and engineers work in the classroom with university personnel to implement engineering activities for middle school students. In reviewing this literature, it became clear that as an academic subject not traditionally taught in K-12 that spans disciplines, engineering represents a new set of content knowledge for teachers. The premise of this project would ask teachers to bring this content knowledge into their pedagogical domain and so the discussion of pedagogical content knowledge became important. Research suggests several barriers to teachers successfully bringing engineering into their classroom including personal and environmental aspects.
Teachers and administrators may also see differently when it comes to evaluating the success of these endeavors.

The second major goal of this review was to establish the theoretical foundation of my research. In doing this, I provided background in negotiated order theory that underlies Gray (1989) which is built upon by other research on collaboration including the dimensions from Thomson et al. (2007). Although Thomson et al. (2007) was the main framework used in analysis as described in Chapter 3, it was not designed for this context. For this reason, it became important to corroborate this interpretation of collaboration with literature from other contexts and provide the broader perspective from Gray (1989). Bringing Thomson et al. (2007) into the K-12 and industry partnership context is a potentially significant contribution of my research. Much of the literature discussed here present a best-case scenario for collaboration. But just as new teachers may feel a tension between what they would like to accomplish in the classroom and what is possible (Pillen, Beijaard, & den Brok, 2013), collaborations can be considered on a spectrum and as an emergent process (Gray, 1989). Lastly, part of this recontextualization also included special emphasis on implications for industry and the VT PEERS project.

It is clear through this review that no single theoretical perspective is enough to establish a robust theory of collaboration, particularly in the context of an interorganizational collaboration focused on K-12 STEM education. For practical purposes, the framework provided by Thomson et al. (2007), as supported by other literature, provided an a priori framework of analysis as presented in Chapter 3.
Chapter 3. Methods

Introduction

The purpose of this research is to contribute to a better understanding of how interorganizational relationships centered around K-12 STEM develop and change during the initial stages of development and the implications for future collaborative success. In their research on corporate-community partnership, Googins and Rochlin (2000) pose considerations for future researchers including exploring how we can develop an understanding of how mutually beneficial collaborations form and become successful. Studying collaboration as an emergent phenomenon in the first year of a structured interorganizational relationship was important to establishing factors of success for future years of the collaboration and ultimate sustainability.

The conclusions of this study contribute to the pre-college education literature on methods of engaging school systems to bring more engineering into the classroom and help address the national calls for improved STEM workforce development. Additionally, much of the empirical work exploring collaboration in similar contexts to this research emphasizes practical outcomes. Although this was important, there was a need for empirical work that interprets interorganizational collaborations in the context K-12 STEM education while grounded in the theory of collaboration presented in Chapter 2. Informed by frameworks of collaboration from Gray (1989) and Thomson et al. (2007), I conducted a multiple case study design to address the following sequential questions motivated by the research and programmatic goals of the VT PEERS project and literature on collaboration.

1) How do stakeholders characterize the collaborative processes in each county-level partnership?

2) What collaborative processes emerge across these county-level characterizations within the broader VT PEERS project?

In a way, this inquiry sought to “test” the viability of these frameworks in the K-12 STEM education context. In the following sections, I will explain the reasoning behind the chosen case study methodology and detail the case construction, methods of data collection, and analysis.
methods. Measures of quality for this research inquiry will also be discussed using the framework provided by Walther, Sochacka, and Kellam (2013).

**Overall research design.** This investigation used a multiple case study approach to investigate the evolution of the first year of a multi-year collaboration involving public educational systems (i.e., school divisions and an institution of higher education) as well as science and engineering companies. Case study research is appropriate for studies in which the contextual conditions are important to answering the research questions. Yin (2014) offers the following two-part definition of a case study: “a case study is an empirical inquiry that investigates a contemporary phenomenon (the “case”) in depth and within real-world context, especially when the boundaries between phenomenon and context may not be clearly evident” (p. 16). As Yin (2014) explains it, contemporary phenomenon simply means studying the observable present or recallable recent past. This collaboration is complex and involves multiple transitory parties, and a case study approach is necessary to capture as many of these contextual conditions as possible. I conducted a multiple case study design consisting of three cases – one for each school division and corresponding industry partner to be bounded by the first year and their geographic location in Virginia. Case study research has multiple data sources in order to triangulate findings (Stake, 2006). In this investigation, the data sources were semi-structured interviews conducted at the start and end of the first year with each collaborative stakeholder with questions based on Thomson, Perry, and Miller (2007) as well as Mattessich et al. (2001). Case studies methodologies that rely on a primarily qualitative approach are prevalent in the literature (e.g., Abma & Stake, 2014; Baxter & Jack, 2008).

**Philosophical perspective.** Philosophical perspectives have an impact on the way research is conducted and should be considered explicitly (Creswell, 2014). This dissertation research was primarily performed from a pragmatic epistemological perspective. Scholars of this philosophy include Peirce, who first attempted to define the term, as well as James, Lewis, Dewey, and Mead (Thayer, 1982). Drawing on the works of these early scholars and more modern adaptations, Creswell (2014) explains that pragmatist researchers are motivated by using any and all means to develop solutions to the research problem. Put another way, a pragmatic approach allows for selection of the most appropriate methodology for the needs of the specific inquiry at hand (Patton, 2002). Pragmatists believe in the importance of considering both quantitative and qualitative methodologies as appropriate, and that research takes place in its
broader socio-cultural contexts (Creswell, 2014). For this reason, the context-dependent nature of case study research is particularly appropriate as an orienting methodology in the pragmatic paradigm. Questions of ontology, whether reality is dependent or independent from the individual’s mind, is less important to the pragmatic researcher (Creswell, 2014).

In consideration of the pragmatism worldview, although this study helps advance the scholarship around collaboration and pre-college engineering education research, more practically it also helps the VT PEERS project team advance the goals outlined in Chapter 1. I sought to gain a better understanding of the experience of the stakeholders during the initial stages of collaboration but at the goal of improving the partnership and advancing the outcomes of the collaboration as well as being able to translate the results to new contexts. All aspects of the inquiry were oriented to questions that were important to the programmatic impacts (e.g., sustainability of partnerships). Methods of data collection and analysis were chosen in direct relation to accomplishing these goals and developing results that address the questions posed.

Statement on qualitative research. Consistent with the pragmatic perspective, I took a more structured approach to qualitative inquiry as opposed to a mostly inductive design. Miles, Huberman, and Saldaña (2013) succinctly articulate the trade-offs involved in this decision particular to multiple case study designs.

In multiple-case research, for example, the looser the initial framework, the more each researcher can be receptive to local idiosyncrasies—but cross-case comparability will be hard to get, and the costs and the information load will be colossal. Tightly coordinated designs face the opposite dilemma: They yield more economical, comparable, and potentially generalizable findings, but they are less case sensitive and may entail bending data out of contextual shape to answer a cross-case analytic question (p. 20).

In his discussion of pragmatism, Patton (2002) orients himself between the purely naturalistic inquiry advocated by Lincoln and Guba (1985) and the other extreme of assessing randomized experimentation to be the epitome of quality research. In alignment with the pragmatic paradigm, a compromise in this research was to allow for some open coding beyond the a priori framework established for analysis while still maintaining a structure for adequate comparability across cases and to other contexts. A middle ground approach that allows for at least some freedom in coding also made sense for this inquiry, because although the frameworks
of collaboration discussed in Chapter 2 are well-supported, they needed to be recontextualized for this research study. This trade-off will be reiterated in the discussion of the specific analysis techniques.

VT PEERS Study Context

**NSF project overview.** It is important to detail the context in multiple case study designs because case studies explore phenomena that are hard to separate from their context (Stake, 2006; Yin, 2014). As discussed in Chapter 1, this work takes place within the Virginia Tech Partnering with Educators and Engineers in Rural Schools (VT PEERS) project. The research and programmatic activities were funded through the NSF ITEST program. Outreach and research through this project is primarily motivated by the idea that there are barriers for rural and Appalachian students to pursue engineering as a future career (Carrico & Matusovich, 2016).

The VT PEERS project team is facilitating partnerships between school educators and local engineers from industry to produce activities for middle school students to develop engineering knowledge and skills while developing interest in and knowledge of diverse engineering career pathways including non-bachelor requiring but highly skilled technical careers. In the current structure, teachers and industry partners have agreed to one classroom intervention per month and to attend a summer summit at which team building and curricular activities will take place. The classroom activities align with science standards already in use by the teachers’ school counties and the Next Generation Science Standards explored in Chapter 2. The major curricular elements that each of these interventions centers around include: aligning with existing learning standards, emphasizing hands-on classroom activities, forging connections to engineering thinking or engineering careers, and creating relevancy for rural and Appalachian youth.

Evaluating criteria used to design and assess the efficacy of the lesson designs were adapted from Cunningham and Lachapelle (2014) and provide a window into the types of lessons this program brings to the school systems involved. These overarching categories and sub-criteria are listed in Table 1.
Table 1. Criteria adapted from Cunningham & Lachapelle (2014)

<table>
<thead>
<tr>
<th>Overarching Criteria</th>
<th>Sub-criteria for assessing and design classroom interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment with learning standards</td>
<td>• Alignment with Virginia Standards of Learning and Next Generation Science Standards (direct/explicit or indirect/implicit connection)</td>
</tr>
</tbody>
</table>
| Scaffolding of student work                   | • Models and makes explicit the practices of engineering.  
• Assumes no previous familiarity with materials, tasks, or terminology.  
• Produces materials that are flexible to the needs and abilities of different kinds of learners. |
| Learning in a local, real-world context       | • Narratives are used to develop and motivate students’ understanding of the place of engineering in the world.  
• Demonstrates how engineers influence people, animals, the environment, or society.  
• Provides engineering/technology examples from youths’ local community. |
| Design challenges are authentic to engineering practice | • Design challenges are open-ended with more than one correct answer.  
• The role of failure is discussed as part of iterative design.  
• Cultivates collaboration and teamwork.  
• Engages students in active, hands-on, inquiry-based engineering. |
| Everyone engineers and everyone can engineer | • Cultivates learning environments in which all students’ ideas and contributions have value.  
• Fosters children’s agency as engineers.  
• Develops challenges that require low-cost, readily available materials.  
• Provides engineering role models from youths’ local community.  
• Provides examples of engineering/technology careers from youths’ local community. |

The three collaborations across the three school divisions share nearly all the same activities with some variations due to school schedules and snow days. Table 2 depicts the timeline of implementation and titles for each of these activities for each school and school division. Teachers identified standards and the appropriate time of year they should be addressed according to county pacing guides which also accounts for some of the variation even though the actual learning standards addressed are the same across cases.
Table 2. Timeline of programmatic activities by school division

<table>
<thead>
<tr>
<th>School Division</th>
<th>Month</th>
<th>Topic</th>
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</thead>
<tbody>
<tr>
<td><strong>Springfield County Public Schools</strong></td>
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<tr>
<td>Belmont Middle</td>
<td>Sep-17</td>
<td>Scientific Method</td>
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<td></td>
<td>Oct-17</td>
<td>Osmosis and Diffusion</td>
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<td></td>
<td>Feb-18</td>
<td>Ecosystem Interaction</td>
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<td></td>
<td>Mar-18</td>
<td>Scientific Method Revisited</td>
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<tr>
<td></td>
<td>Apr-18</td>
<td>Water Filtration</td>
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<tr>
<td>Alton Middle</td>
<td>Oct-17</td>
<td>Scientific Method</td>
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<td></td>
<td>Oct-17</td>
<td>Osmosis and Diffusion</td>
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<td>Feb-18</td>
<td>Scientific Method Revisited</td>
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<td>Ecosystem Interaction</td>
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<td>Apr-18</td>
<td>Water Filtration</td>
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<td><strong>New County Public Schools</strong></td>
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<td>Haile Elementary/Middle</td>
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<td>Scientific Method</td>
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<td>Nov-17</td>
<td>Periodic Table</td>
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<td>Dec-17</td>
<td>Potential and Kinetic Energy</td>
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<td>Walter Filtration</td>
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<td></td>
<td>Mar-18</td>
<td>Scientific Method Revisited</td>
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<td></td>
<td>Apr-18</td>
<td>Earth and Space</td>
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<tr>
<td>Lane Elementary/Middle</td>
<td>Oct-17</td>
<td>Scientific Method</td>
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<td>Nov-17</td>
<td>Periodic Table</td>
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<td></td>
<td>Dec-17</td>
<td>Potential and Kinetic Energy</td>
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<td></td>
<td>Mar-18</td>
<td>Scientific Method Revisited</td>
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<td>Apr-18</td>
<td>Earth and Space</td>
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<tr>
<td>Chandler Elementary/Middle</td>
<td>Oct-17</td>
<td>Scientific Method</td>
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<td>Scientific Method Revisited</td>
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<td>Earth and Space</td>
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<td><strong>South County Public Schools</strong></td>
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<td>Meadowfield Middle</td>
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<td>Scientific Method</td>
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<td>Apr-18</td>
<td>Earth and Space</td>
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<td>Jefferson Middle</td>
<td>Oct-17</td>
<td>Scientific Method</td>
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<td></td>
<td>Apr-18</td>
<td>Earth and Space</td>
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As illustrated by Table 2, nearly all the schools and counties participated in the same engineering-themed activities during approximately one visit per month from the Virginia Tech project team. During the first and last sessions, students filled out an engineering identity survey (Capobianco, French, & Diefes-Dux, 2012) and completed the Draw an Engineer Test (Knight & Cunningham, 2004). Again, the student-level research is outside the scope of this research. Although students could be considered stakeholders impacted by the collaboration, they do not share in any of the decision-making, goal-setting, or other hallmarks discussed in the literature in Chapter 2. Deciding which stakeholders are important to include in the study of a collaboration is an important step in this field of study.

Examples of some of the student activities from Table 2 are detailed here to provide some context in which the in-person collaborative activities between teachers and industry partners took place. To start, the activity intervention based on the scientific method required students to complete a broken flashlight troubleshooting activity. Students identified independent variables (e.g., burnt bulb, missing batteries, broken connection) and a dependent variable (i.e., the flashlight lights or does not light), generated a hypothesis, and tested their predications. As another example of an engineering-themed activity aligned with science standards of learning, students explored potential and kinetic energy by building “mountain roads” out of simple hardware store materials. This activity also clearly demonstrated the local relevancy emphasis in the lesson designs as students made connections between the classroom roads and the geography of their own mountainous, rural area. In both cases, industry partners brought insights from their technical background or company practices and assisted with the hands-on lesson.

**Broadening participation in engineering and the rural setting.** The VT PEERS project is guided in part by the idea that despite some successful efforts towards broadening participation in engineering, significant challenges still remain. Although learners everywhere face these challenges, they are felt keenly in rural areas in particular. Looking to a program similar to VT PEERS in which the university system partnered with rural school districts in Florida highlights unique challenges for the rural context including limited access to high quality precollege education and large physical distances from population centers and their associated resources (Sepanik, Safran, & Saco, 2018). There is also a lower amount of technical “white-collar” jobs (Seufert & Carrozza, 2004) compared to “blue-collar” jobs in the rural and Appalachian community and potentially less role models for an engineering career. In framing
their study of school-community partnerships in Virginia, researchers identified that young rural Virginians face issues of poverty, lower level of education, lower salaries, and higher drop-out rates (Alleman & Holly, 2012). In characterizing the case sites in the sections below, it will become clear that many of these issues are relevant to this investigation as well. Embedded in these challenges lies opportunities such as leveraging perceptions of engineering around fixing and manual work into relevant engineering activities (Gillen, Grohs, Matusovich, & Carrico, 2017).

**Researcher role.** In all research, but particularly research involving multiple investigators, it is important to clarify the researcher role. In the VT PEERS project, I have designed curriculum and assisted in facilitating classroom interventions. I have also participated in the refinement of research tools such as the interview protocol and conducted interviews along with the research team on the project. I analyzed interview data, as well as reported and interpreted findings in the context of contemporary literature.

**Case Construction**

According to Yin (2014), although it is tempting to refer to cases as purposive samples, the terminology around sampling should be avoided for the implication that the case is a simple subset of a population. Instead, the terminology of selecting cases is offered up as an alternative, and justification for the case construction will be provided. As mentioned at the start of this chapter, case study research is appropriate when the phenomena of interest are hard to separate from their context. In his newer edition, Yin (2014) stands by this original guiding definition for case study research but adds the caveat that “the lack of sharpness between phenomenon and context does not minimize the need to identify a “case” and its singularity as the essential feature of a case study” (p. 24). In this section case construction and participants in each case are described in detail. The phenomenon of interest is collaboration as it evolves and emerges in the first year of the project. Recall that collaboration as an emergent process is an appropriate lens for which to view this field of research (Gray, 1989).

Because the individual school divisions and industry partners share the partnership with the university and the same activities, but do not significantly interact with each other, the project can be thought of as three separate collaborations within an overarching collaborative project. For this reason, I implemented a case study design adapted from case study types
presented by Yin (2014). The context is both different (e.g., these are different school counties with different institutional norms and practices) and simultaneously the same (e.g., they share the VT PEERS engineering activities and are all rural communities, and the university partner is common to all). The embedded units of the different stakeholder groups are an important component of the design as they helped address the first sequential question. Taking each case holistically and comparing across cases within the similar context helped address the second sequential research question. Yin (2014) suggests, for example, if doing a case study with multiple schools, “each school might be the subject of an individual case study, but the study as a whole covers several schools and in this way uses a multiple-case design” (p. 56). Because industry is partnered with school counties and not just individual schools, it makes sense in this study of the collaboration phenomenon to bound a case by the school county, but in a similar way to Yin’s (2014) illustrative example. Figure 1 depicts this multiple case study design and how it emerged from the structures provided by Yin (2014). In case study research, the case itself is the unit of analysis.
Figure 1. Case Study Design Between Type 2 and Type 4. Reproduced and adapted from Figure 2.4 “Basic Types of Designs for Case Studies” from Yin (2014) (p. 50).
This design co-ops the shared context of the type 2 and the multiple cases and embedded units of a type 4 case. The distinction of the phrase embedded unit of analysis shown in Figure 1 is that it is both a building block of the overall case analysis and an object of separate analysis in-and-of-itself. To further clarify, units of analysis are not the same as units of data collection in case study research (Yin, 2014).

When applied to my study, this design yielded cases for each of the three sub-collaborations underneath the banner of the larger VT PEERS project collaboration. These include the collaboration Virginia Tech has with South County and Cornerstone Industry, Springfield County and EchoCorp, and New County and Deltax Corporation. This design allowed for answering the high-level, second sequential question around collaboration through a holistic cross-case analysis which built from analysis of the case level and embedded units of the stakeholder groups addressing the first sequential question. One major benefit of having three case sites was the option to examine commonalities across patterns that may be a result of Virginia Tech’s presence across all three contexts. Moreover, the cases had to be separated in this way, as opposed to a single case design, because the stakeholder groups within each case do not interact across case with the exception of the university. Still, it was useful to compare the same stakeholder group across cases in some instances. Figure 2 shows the design adapted from Yin (2014) in the context of this study. Pseudonyms were applied to all organizations and individuals to protect confidentiality.

Figure 2. Multiple case study design with embedded units of analysis.

<table>
<thead>
<tr>
<th>Case #1: South County and Cornerstone Industry</th>
<th>Case #2: Springfield County and EchoCorp</th>
<th>Case #3: New County and Deltax Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers</td>
<td>Teachers</td>
<td>Teachers</td>
</tr>
<tr>
<td>Administrators</td>
<td>Administrators</td>
<td>Administrators</td>
</tr>
<tr>
<td>Industry Partners</td>
<td>Industry Partners</td>
<td>Industry Partners</td>
</tr>
<tr>
<td>University Affiliates</td>
<td>University Affiliates</td>
<td>University Affiliates</td>
</tr>
</tbody>
</table>

Descriptions of the three school counties. As mentioned previously, the three case sites are primarily rural geographic regions. U.S. Census (2016) indicates the population, the median
household income, and the percentage of people over the age of 25 that hold Bachelor’s degrees or higher. Percentage of students receiving free or reduced school lunch can be used as an indicator of relative socioeconomic status for the counties involved in this study. Precise statistics were obtained from the Virginia Department of Education (2017). Again, ranges were reported instead of the actual values for the statistics described above in order to protect the identity of the counties in this investigation. Table 3 summarizes this information for the three counties in this study.

Table 3. Ranges of county level data from U.S. Census (2016) for each case site

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Median household income</th>
<th>Bachelor’s degree or higher</th>
<th>Free and reduced lunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>South County</td>
<td>30,000 - 40,000</td>
<td>$30,000 - $40,000</td>
<td>10% - 20%</td>
<td>50% - 60%</td>
</tr>
<tr>
<td>Springfield County</td>
<td>70,000 - 80,000</td>
<td>$50,000 - $60,000</td>
<td>20% - 30%</td>
<td>30% - 40%</td>
</tr>
<tr>
<td>New County</td>
<td>10,000 – 20,000</td>
<td>$40,000 - $50,000</td>
<td>10% - 20%</td>
<td>40% - 50%</td>
</tr>
</tbody>
</table>

South County and New County fall below the national median household income of $55,322 (U.S. Census, 2016). All counties have a lower percentage of persons aged 25 years or older that hold a bachelor’s degree or higher than the national percentage of 30.3% (U.S. Census, 2016). Also, around half of all students in these counties are receiving a free or reduced lunch. It is clear that these counties are representative for some of the challenges facing rural areas described above such as poverty and lower educational attainment (Alleman & Holly, 2012). It could be argued that they are therefore appropriate choices of counties to draw conclusions about rural areas in the United States more broadly or at the very least that they are appropriate candidates for a research study motivated in part by considerations for broadening participation in STEM to rural populations.

Descriptions of the three industry partners. The specific details of the industry participating employees will be described later. At a higher level, a description of the work each of these companies performs will be provided. Recall that in most cases, these are prominent local industries in science and engineering in each respective case site. Much of the information used below has been taken from the company websites. To protect the identity of the participating industry partners, the company website URLs are not provided in the references.

Cornerstone Industry. Cornerstone Industry is a large, international organization that employs engineers and technicians to produce synthetic fibers. Their explicitly stated business
purposes include creating partnerships in business and supporting the communities their businesses inhabit. They create carpet fibers for multiple applications including, for example, commercial, residential, and automotive uses.

**EchoCorp.** EchoCorp designs and manufactures foams for applications as diverse as automotive, construction, industrial, or athletic purposes. They hire scientists and technicians from a variety of backgrounds to both develop and make the blended foams for these applications. Their in-house research and development tests new designs to develop new products and improve existing designs. This company has personal ties to a member of the VT PEERS project team, and this connection was used to help establish the initial partnership within Springfield County.

**Deltax Corporation.** Deltax Corporation is also a large, international organization that specializes in materials sciences. They design and manufacture a variety of materials for everyday products as diverse as flooring, building materials, appliances, and food additives. Engineering-related industries in which they are involved include agriculture, chemicals, mechanical, energy, building construction, food, medical, printing, cosmetics, and textiles. This description is not exhaustive, but what should be clear is that they focus on designing and manufacturing materials for a variety of applications.

**Participants within each case site.** There are four major stakeholder groups that make up the VT PEERS collaboration and form the sample for this study: administrators, teachers, industry partners, and university affiliates. The literature defines a stakeholder in collaboration as any “individual, group, or organizations that can directly influence the focal problem or issue” or are influenced by others involved (Gray & Purdy, 2018, p. 2). In this study, I have used stakeholders and participants to refer to the individuals most involved in either establishing program governance or implementing classroom activities. Obviously, when considering the issues this program seeks to address within the education system, stakeholders go well beyond the school, university, and business personnel, but these stakeholder groups represent each of the adult participants in the program. Still, why each was important to this investigation and a brief description of the participant group is discussed in the following sections. The schools involved are representative of rural school districts across the country as illustrated by the information provided in the previous section. These communities face the unique challenges related to postsecondary preparedness and future job prospects including the simple notion of having the
opportunity to envision engineering work meshing with the local experiences from their everyday lives. The industry partners chosen for this study are appropriate because in most cases they represent a large and prominent technical workforce present in the community. Because the ultimate goal is sustainability, the local and most well-resourced science or engineering focused company was the clear option. Table 4 depicts the number of participants from each stakeholder group in each case. A total of 76 semi-structured interview transcripts from 49 participants were generated.

Table 4. Number of participants by case.

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Group Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Administrators (School and County)</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Industry Partners</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>University Affiliates</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Case Total</td>
<td>11</td>
<td>16</td>
<td>17</td>
<td><strong>49</strong></td>
</tr>
</tbody>
</table>

Recruitment. The participants in the scope of this work were recruited through the VT PEERS project. The county administrators and industry leadership committed to involvement before the project was funded and principals and teachers opted in afterwards. With permission from the school principals, university affiliates approached sixth grade teachers through short workshop-style sessions and pitched the potential of their involvement in the project. At the end of the first year, seventh grade teachers were invited to participate for the first time and sixth grade teachers were invited to participate again (this time taking more of a leadership role in the activities). No research incentives were offered to school or industry personnel. Teachers, but not industry personnel, are compensated for their time and travel to the summit event but participation in the research component is independent of, and not a prerequisite for, participation in the VT PEERS program. Although not part of this research, the middle school students were invited to participate in the research as well, though their participation in the activities was not contingent on their participation in the research. This first year, every sixth-grade student in participating schools experienced the activities via their science class.

Administrators. Administrators for both the counties and schools were the first individuals approached about the project. Without this leadership support, it is likely that the partnership might not have manifested at all. Furthermore, research suggests that investigating administrators would be important because support and buy-in from administrators is a major
factor in making changes to teaching practice (Berebitsky, Goddard, & Carlisle, 2014). Across the three school counties, individuals at the county administration level (e.g., superintendent or assistant superintendent) and seven principals (one for each school involved) are participants.

**Teachers.** All participating teachers lead science classes at their middle school. They have varying levels of experience and different educational backgrounds. For example, at least one participating teacher was originally trained in social studies education and started teaching science only after working for a number of years. Teachers and other school personnel are central to the development of K-12 engineering education, but their experiences are an underutilized resource when it comes to developing these initiatives (Teacher Advisory Council et al., 2017). The teacher is the individual that ultimately has control over what sorts of learning experiences take place in their classroom, so it was important to understand how teachers view the impact of such collaborations on their teaching practice.

**Industry.** Like the teachers, participating engineers have different levels of experience. For example, one participating engineer has recently graduated and is in an entry level position while others have been working for years. The engineers work in different industries involving chemical and materials engineering, manufacturing, and other engineering subdisciplines. Although they all work in science and engineering jobs, not all of them would describe themselves as engineers, and they hold a variety of job titles. Having industry as explicit participants in this project is important both from a programmatic and research perspective. Existing work in the literature on teacher-industry partnerships identified barriers to bringing the industry content back into the classroom such as the material being too advanced, lack of access to necessary tools, or little understanding of what the company does (Buxner et al., 2014). From a research perspective, the viewpoint of industry in such a partnership is understudied, especially in research focused on teacher professional development. Recall that the goals of the VT PEERS project also center around sustainability. Industry is not an unlimited resource for these school communities. The school divisions are limited by what is nearby and established connections. The industry partners chosen for this study are some of the most prominent in the area and have the capacity to potentially carry on the work after the funding for the project ends.

**University Affiliates.** Programmatic and research personnel on the project were interviewed as stakeholders in the collaboration. It is important to note that their actions as participants cannot easily be separated from their actions as project personnel. Still, as instigators
of the collaboration and a heavy hand in the design and implementation of the activities in this first year, select university affiliates were reasonably recruited as research participants. In particular, insights from a program-focused team member who is in direct contact with teachers and industry partners and has lead facilitation of activities this year was important for characterizing the emerging collaboration.

Data Collection

Case study research often uses multiple sources of data and the triangulation of data (Stake, 2003; Yin, 2014). Although this analysis includes only qualitative data sources, data collection includes a semi-structured interview both before the first intervention of the year and after the last. A survey (Appendix A) was administered before each interview with questions from the validated instrument from Thomson et al. (2007) around collaboration and Yoon et al. (2014) around engineering self-efficacy. While the survey results were not analyzed for this investigation, they primed participants to consider the collaborative processes involved in the project before their interview.

Semi-structured interviews. Open-ended questions discussed through interviewing “permit one to understand the world as seen by the respondents” (Patton, 2002, p. 21) beyond what the closed-ended survey questions could have provided. Before the first intervention and after the last, a semi-structured 30 to 60 minute interview was conducted with both the teachers and the industry participants. The interview protocols used by the VT PEERS team were guided by the five dimensions from the framework of collaboration from Thomson et al. (2007) and Mattessich et al. (2001) (Appendix B). For teachers, it also included considerations of their conceptions of engineering, motivation to teach engineering, reasons for choosing to participate, and engineering self-efficacy, but these questions are outside the scope of this investigation. For this inquiry, it made sense that the majority of the questions asked the participants to think on a collaborative or organizational level. According to Stake (2006), “an interview should be less about the interviewee than about the case” (p. 31).

Post-year interviews included new participants such as industry employees who participated in the classroom but were not originally identified and the South County superintendent who was unavailable for interview at the start of the year. The post-year interview protocol was adjusted to ask interviewees to reflect on changes across the year in part to account
for the lack of a pre-year interview in these instances. Moreover, having participants reflect in this way more directly aligned the research questions with the interview protocol.

**Data management.** To protect the confidentiality of participants, interview transcriptions were cleaned of identifying information and stored on a secure sever. The clean transcripts were analyzed using data management software to track codes across multiple documents. To further protect participant identities, because gender was not salient to results, and because participants were not asked their pronouns, the word “they” is used as a singular pronoun throughout the presentation of results. According to the International Writing Centers Association “singular they has a long history in spoken and written English...it permits writers to avoid specifying a gender when doing so may be irrelevant, inappropriate, or needlessly restrictive” (International Writing Centers Association, 2018).

Tracking of data collection used a spreadsheet developed for the pre-year surveys and interviews. It indicates the participant and relevant characteristics, confirms their consent document is signed and on file, and maps the interview logistics from scheduling to uploading a completed transcript. This was important for maintaining consistency as multiple interviewers processed data they collected.

**Data Analysis**

Please recall that the research questions addressed in this study are as follows:

1) *How do stakeholders characterize the collaborative processes in each county-level partnership?*

2) *What collaborative processes emerge across these county-level characterizations within the broader VT PEERS project?*

Answering the second, overarching question required the construction of an understanding of how an interorganizational partnership develops and emerges in the first year in this context. In order to gain this holistic understanding at both within-case and cross-case levels, it was necessary to consider individual stakeholder perspectives. Answering the first sequential question through considerations of the embedded units of analysis of the stakeholder groups and comparing across these embedded units helped build the case-level understanding of the individual school county-industry collaboration and cross-case level understanding of the whole
VT PEERS collaboration. In this way, the questions build from first (case-level) to second (cross-case, overarching) from analysis at the embedded unit of stakeholder level to whole case to cross-case. This case study analysis follows the general strategy from Yin (2014) to use the initial theoretical perspectives presented to structure the analysis. In this instance, these include the works from Thomson et al. (2006, 2007) in consideration of the research on collaboration from Gray (1989) and others.

**Qualitative analysis.** As mentioned previously, there is a trade-off between tight and loose designs in qualitative research. While tight designs offer a more streamlined analysis process and increase comparability, loose designs help ensure the integrity of the interpretation of the participant’s social reality. I have argued that an a priori framework of analysis was appropriate for analyzing the high quantity of interview transcripts and drawing conclusions on a broader scale of the collaboration. This was consistent with the pragmatic goal of developing an understanding of the research problem as it aligns with program goals. Still, any insights that fell outside of these predetermined categories, but were imperative to explaining the case, were important to include in any final results. Fine tuning of this approach was necessary and adaption in the case study design in this way was appropriate based on unforeseen information gained through data collection (Yin, 2014). Because of the volume of interview transcripts and the higher-level results demanded of the overarching research question, the qualitative analysis consisted of holistic coding techniques in which larger sections of data were coded at once as opposed to individual lines (Miles et al., 2013). Because the Thomson et al. (2007) framework was adapted for use a priori in analysis, the method of coding was primarily deductive while leaving room for some open interpretations as described above (Miles et al., 2013). Table 5 provides a definition for each of the dimensions from Thomson et al. (2007). In this investigation, I explored how these collaborative aspects developed or changed during the first year. It is also important to note that these codes were not mutually exclusive, particularly in the pre-year interviews from the start of the collaboration where individuals were still grappling with their respective roles. For example, in a statement explaining perceived commitments from another partner, they may be simultaneously bounding their own roles and obligations.
Table 5. Dimensions from Thomson et al. (2007) and definitions

<table>
<thead>
<tr>
<th>Collaboration Construct</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance</td>
<td>Negotiated process of developing working rules and structures around collaborative participation.</td>
</tr>
<tr>
<td>Administration</td>
<td>Implementation and management of governance structures including clarifying operating mechanisms such as participant roles, communication processes, and monitoring.</td>
</tr>
<tr>
<td>Organizational Autonomy</td>
<td>The pull between individual organization and collective interest.</td>
</tr>
<tr>
<td>Mutuality</td>
<td>“Beneficial interdependencies” based on either a complimentary exchange of resources or a shared interorganizational mission.</td>
</tr>
<tr>
<td>Norms of Trust and Reciprocity</td>
<td>Perceived relative degree of obligation or &quot;I will if you will&quot; and evolving beliefs about partner commitments.</td>
</tr>
</tbody>
</table>

Cross-case analysis. According to Yin (2014), one method of cross-case analysis is synthesis across multiple cases. He argues that this is appropriate for a case study design consisting of two or more cases and is a way to strengthen findings. A cross-case synthesis can also be structured to draw conclusions at a higher level than the individual cases (Yin, 2014). This larger, overarching case becomes a new unit of analysis. In this study, this overarching consideration was the entire VT PEERS project during the first year and an understanding was developed by cross-case analysis of the three individual county-industry collaborations. In a similar way, comparisons across the embedded units of analysis (the stakeholder groups) were made to help establish this broader interpretation. Once the case summaries by stakeholder group by construct were completed as presented in Chapter 4, I began to look for patterns across cases and exceptions to those patterns. For example, the cross-case finding Industry investment had to do with both perceived capacity and company philosophy emerged from considering how each industry partner talked about autonomy issues. It became clear that Cornerstone and Deltax had a different approach to participation rooted in their organizational norms than EchoCorp. A step by step guide of how the analysis developed through what has been described here to the cross-case interpretations is provided in Figure 3 and an illustration elaborating on the individual steps is provided in Figure 4. The step numbers in Figure 3 are broken down into components (e.g., 2a, 2b, etc) in Figure 4.
Figure 3. Overall analysis guide

Steps in Analysis

How do stakeholders characterize the collaborative processes in each county-level partnership?

Step 1: Coding individual interview transcripts
The first step was the coding of the individual transcripts from the pre and post year interviews using Thomson et al. (2007) as an a priori framework and allowing some room for inductive coding. At this stage, excerpts were flagged with respect to a construct because a single stakeholder perspective alone could not provide the full understanding of these interactional components. These labels shifted and informed one another as I built to the case-level.

Step 2: Case-level analysis
The second step was to summarize these categories across stakeholder groups within each case, building a summary for each. Each stakeholder group summary highlighted the most significant findings. Taking these together yielded a conceptualization of the whole case. The goal was to quickly aggregate to the case level in order to make cross-case comparisons in the final step.

What collaborative processes emerge across these county-level characterizations within the broader VT PEERS project?

Step 3: Cross-case synthesis
The final step was the cross-case synthesis in which I took the case interpretations for each county and compared them. Using summary tables generated through the previously described analysis steps aided comparison. Creating tables that display case level data along certain categories was consistent with cross-case synthesis methods from Yin (2014). I also used analytic memoing techniques in steps two and three to reflect on my analysis process as I built to the higher level (Miles et al., 2013).

Unit of Analysis

Step 1
Unit of analysis:
Individual stakeholder (e.g., teacher in New County)

Step 2
Embedded unit of analysis:
The stakeholder group (e.g., industry partners within a case)
Unit of analysis:
The case (e.g., South County and Cornerstone Industry)

Step 3
Embedded units of analysis:
Each of the three cases
Unit of analysis:
The overall VT PEERS partnership
Figure 4. Expanded view of the steps in analysis

**Step 1: Coding interview transcripts** from all participants in a case primarily across the five constructs from Thomson et al. (2007)

- Mutuality
- Norms of T & R

**Step 2a (Case-level): Generating summaries by stakeholder group** by construct (e.g., teachers on organizational autonomy) by comparing excerpts within a group

Stakeholder group summary around each construct

**Step 2b (Case-level): Comparing and synthesizing stakeholder summaries to generate case-level write ups**

- Teachers
- Administrators
- Industry
- University

Case summary including perceptions of collaborative processes from each stakeholder group for each construct

**Step 3a (Cross-case): Mapping similarities and differences** across cases both within and across constructs (e.g., differences in views around organizational autonomy across cases)

**Step 3b (Cross-case): Drafting succinct statements to summarize these similarities and differences** (8 cross-case assertions in Ch4)
Limitations

There are several limitations that may have influenced the quality and impact of this investigation. In this section, I will discuss these potential limitations and offer circumstances that mitigated or lessened their effect on the study outcomes. To start, Stake (2006) notes that in case study research, prescribed coding runs the risk of reducing complexity to discrete categories. For instance, grouping in this way required decisions to be made about where to place findings that spanned the often-interactional processes that make up the framework of collaboration used in analysis. This is why some of the findings may appear as though they could belong to more than one construct as presented in the results (e.g., communication in governance versus administration). Risks of a priori coding were partially mitigated by allowing for some inductive coding to take place as described in the analysis details. The ability to analyze and draw conclusions across cases outweighed the risk of reducing complexity, and this approach aligns with the pragmatic worldview.

There were also some limitations to the pre-year data that are important to mention here. Not all those interviewed at the end of the year had pre-year interviews. In most cases, this refers to industry participants that were not previously identified but ended up playing a role in the classroom activities and the collaboration. In South County, notably, the superintendent of schools was not able to be interviewed at the start of the year but was interviewed in a post-year session. The post-year interview protocol was adjusted to counteract some of the negative effects of not having a pre-year interview for every participant. For example, in the post-year protocol, participants were asked to reflect over the year as a whole on multiple aspects of the collaboration. Another consideration impacting the quality of the pre-year interviews is that the original industry partner for New County decided not to continue with the program at the start of the year. They were quickly replaced by Deltax Corporation but in the pre-year interviews with the principals, county administration, and teachers of New County, when they talk about the industry partner, they are sometimes referring to the original industry partner and not Deltax. Again, the adjustment of the post-year protocol mitigated some of these issues and allowed participants to talk across the whole year’s activities.

Lastly, there were some limitations inherent in designing for social research. Though this generally refers to quantitative data collection, Singleton and Straits (2010) indicate two forms of potential response bias that are still salient here: social desirability and acquiescence response.
Social desirability refers to the idea that participants may provide answers that they believe are more socially acceptable. Reiterating to participants that all answers are anonymous can mitigate this bias (Singleton & Straits, 2010). Acquiescence response refers to the inclination towards more agreeable responses. Given the national rhetoric around collaboration and STEM education, and the fact that the researcher is seen as a VT PEERS partner and not a third party, participants may have given answers that they believed were more socially acceptable but not as accurate.

**Researchers bias.** Identifying and explaining researcher bias based on personal experiences is important in qualitative research inquiries (Creswell, 2014). Experiences in my personal and professional life have brought me close to the educational process. Choices made pertaining to this research may have been influenced by my experiences in K-12 education. I taught students K-12 in formal and informal educational settings and taught engineering at the secondary level for a short time. Based on my background, I grapple with the problem that most of the research around teacher development is rooted in the deficit model (i.e., that teachers are lacking in some critical knowledge, experience, or resource). This notion falls in direct opposition to my personal belief that teachers should be valued for their expertise, that their job should be treated as a profession, and my career goals to elevate the associated status of teaching careers. I mentioned in Chapter 2 that teachers in many societies outside the U.S. enjoy more respect and status (Dolton & Marcenaro-Gutierrez, 2013). In exploring the status quo of the U.S. education system and the continual shifts in practice thrown at teachers, I sadly understand why from a researcher or policymaker perspective that they always seem to be falling short.

Qualitative research methods, exploring the rich experience-based knowledge that teachers and other stakeholders have, has the capacity to both address “deficits” and respect the teacher as an individual and professional. I also think that discussing deficits in terms of teacher knowledge is different from discussing deficits related to the school environment. As a researcher, I feel compelled to ensure that I consider the broader systemic problems that prevent teachers from doing their jobs (e.g., long hours, low pay, poverty, crime in schools) before making a judgement on a lack of teacher motivation to pursue a new educational initiative, and base conclusions in results produced from rigorous methods.

As a final thought on researcher bias, there are a few considerations related to deriving this research from a funded project within an academic department. There was the benefit of
collective decision making of the research team on the VT PEERS project. This was a step towards mitigating some of the researcher bias discussed above. At the same time, it is important to note that these same researchers were participants in the research and interviews with people I work with encompass part of this project. Detailing my role and describing their roles in the project was important in making clear conflicts of interest from having research collaborators as participants in the research.

**Research Quality**

This investigation used the qualitative research quality framework offered up by Walther et al. (2013). The framework synthesizes traditional writings on research quality and provides guidelines for qualitative researchers in engineering education to structure their research in “making the data and handling the data” (p. 638). In plain language, making the data refers to sampling and data collection and handling the data is processing and analysis. Recent research in engineering education has used this framework to guide research quality measures (Kirn & Benson, 2018; McNeill, Douglas, Koro-Ljungberg, Therriault, & Krause, 2016). Before I delve into each dimension of the research quality framework, it is important again to consider the purpose of the research in accordance with the pragmatist perspective. Patton (2002) says “pragmatism means judging the quality of a study by its intended purposes, available resources, procedures followed, and results obtained, all within a particular context and for a specific audience.” (p. 71-72). This means that although it is important to ensure research quality in accordance with external standards accepted by the field such as Walther et al. (2013), any judgement should be tempered with an evaluation of the research based on its alignment with the research problem and intended goals previously outlined.

For each dimension below, a definition and supporting literature are provided. I will then explain how this study addressed the requirements based on that definition. Lastly, as this is a case study design, insights from case study methodologists were considered where appropriate. Table 6 is an adaptation of Table 1 from Walther et al. (2013) that depicts the typology of the quality strategies presented in their work. In lieu of the examples they provide, specific strategies for this investigation are provided in the table. Both the definitions from Walther et al. (2013) and the specific strategies for this investigation are elaborated upon in the sections below.
Table 6. Descriptions of data quality constructs and specific study strategies. Adapted from Table 1 “Typology of Quality Strategies” from Walther et al. (2013) (p. 640).

<table>
<thead>
<tr>
<th>Description</th>
<th>Making the Data</th>
<th>Handling the Data</th>
</tr>
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<td>The research process needs to be able to capture the full extent of the social reality studied.</td>
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**Theoretical validation.** This first dimension from Walther et al. (2013) deals with the appropriateness of the theoretical foundation for the social reality under study. Recall that the authors split the assessment of research quality into two categories: making and handling the data. In making the data, Walther et al. (2013) cites the suggestion from Lincoln & Guba (1985) to conduct the research in an authentic setting. Although the interview format was a contrived setting, the cumulative data sources for each case form basis for data collection that is rooted strongly in the context and allows for flexibility based on “the emergent nature of social reality” (Walther et al., 2013, p. 641). The authors also suggest purposive sampling methods, again
borrowing the term from Lincoln & Guba (1985). It was previously suggested that the focus on case construction is more appropriate in case study research than an emphasis on sampling (Yin, 2014). Still, these cases were chosen because they are a good fit to research on the rural context and interorganizational research.

In handling the data, researchers need to ensure that they are capturing an authentic reflection of the complexity of the social reality. Inductive analysis is suggested as a means to ensure theoretical validation in handling the data. Recall that the analytic technique in my study was primarily deductive and used an a priori framework. However, the analysis also left open new inductive codes to be made during the analysis process as they emerged. Although this trade-off was discussed as a limitation, recall that the benefits of being able to build to a cross-case comparison offset the limitations of relying mostly on deductive coding.

**Procedural validation.** The second validity construct connects directly to the theoretical validation. It requires the researcher to denote specific strategies towards ensuring the fit between theory and social reality. In making the data, Walther et al. (2013) suggest data triangulation, multiple sources to confirm interpretations, to ensure procedural validation (Maxwell, 2005). Recall that pre-year and post-year data was analyzed to substantiate findings through a form of qualitative triangulation of data (Stake, 2006). In handling the data, procedural validation entails “systematic and documented processes of analysis and interpretation” in order to reduce the chance of inaccurate interpretations of participants’ social reality (Walther et al., 2013, p. 622). Both in handling and making the data, one way of promoting this form of validation is to carefully consider researcher bias. Walther et al. (2013) refer to the explicit consideration of researcher bias when making interpretations as interpretive awareness from Sandberg (2005). I have provided a statement on researcher bias to both temper certain conclusions drawn from the research and to reflect on how my personal and professional experience might impact my interpretation.

**Communicative validation.** The third validation construct from Walther et al. (2013) requires that knowledge be constructed not only within the social context of the study but also within the appropriate research community. In making the data, suggested strategies include member checks and considering any contrasting accounts from participants. As a case study analysis, contrasting accounts or rival explanations (Yin, 2014) were considered explicitly in order to answer the research question and build an understanding of how the collaboration
emerges in the first year with the understanding that differing accounts may be a research finding in-and-of-itself and not a data quality issue. Informal member checks were performed through the project’s programmatic activities in the classroom and in our regular communications. Creswell (2014) defines member checking as communicating refined information to the participant to check your interpretation. This was done in part during the post-year follow up interviews with participants.

Communicative validation in handling the data has two parts: interpretations being based in the participants’ accounts as discussed in making the data and presenting results and interpretations in a manner consistent with the practices of the discourse community that the research is embedded within. Towards this goal, I have established that the frameworks of collaboration guiding this inquiry were also used in analysis and to situate the research. Moreover, Walther et al. (2013) cite the simple notion of using the correct terminology for the discourse community (Kirk & Miller, 1986). Because the framework of analysis was primarily a priori, the interpretation of the results naturally fell into these pre-established categories in the literature community around collaboration. As a more concrete suggestion, the use of peer debriefing (Lincoln & Guba, 1985) through regular VT PEERS team meetings also promoted communicative validation in handling the data. Comparing interpretations of the same data was very feasible given the size of the team of researchers involved in the VT PEERS project.

**Pragmatic validation.** The fourth validity construct from Walther et al. (2013) asks researchers to consider how well the theory and literature compare with empirical results. It is here that Walther et al. (2013) also talks about generalizability and transferability. Because the primary data collection method in this investigation was qualitative in nature, it makes sense to emphasize transferability (Guba & Lincoln, 1982) over generalizability. In qualitative research, researchers provide a detailed description of the context so that others can determine the applicability or connections to their context (Borrego, Douglas, & Amelink, 2009). Detailing the overarching study was an important aspect of this chapter and providing careful descriptions of the context will continue to be an emphasis as results and discussion are presented.

Specifically in making the data, one suggested strategy from Walther et al. (2013) is to ensure a diversity of participants. In this study, although I have argued that the rural contexts are similar, the personal and professional backgrounds of the individual participants varied widely. For example, some of the science teachers in this investigation have backgrounds in science
teaching while others do not. Similarly, some of the industry participants identify as engineers while others, although they do engineering work, choose not to use the label in discussing their work. This diversity of backgrounds and perspectives helped ensure pragmatic validation in making the data.

In handling the data, pragmatic validation asks if the theoretical interpretations resonate with existing and similar contexts. In an example from Walther et al. (2013), their data collection process and feedback from participants lead to the development of a teaching tool. In the VT PEERS project, these research findings will be directly incorporated into the remaining years of practice.

**Process reliability.** The strategies provided for process reliability help the researcher to mitigate random influences on the research process. For making the data, data collection needs to be standardized and its quality ensured in some manner. All interviews were recorded using two recorders in case of failure, and the digital recordings were transcribed verbatim. Transcripts were checked for errors made in transcription (Creswell, 2014). Another suggestion from Walther et al. (2013) is to provide training for data collection for consistency. Multiple interviewers collected data from participants in this project. Interview guides were developed for the pre-year interviews and changes made to the protocol and procedure were discussed as a group. New individuals that joined the interviewing team were given individual instruction in how to collect the data in a similar manner in which it has already been done and will continue to be done. Spreadsheets tracking the data managed the manner in which the data was collected across researchers.

For handling the data, documenting the analysis procedures was important. For this I kept a chronological reflective research journal in which I recorded memos to myself during the analysis process to record detail descriptions of how I formed the interpretations. The researchers also suggest multiple levels of coding to make clear the difference between what is strictly in the data and where the investigator’s interpretations start to emerge. This occurred naturally through the analysis described above.

**Ethical validation.** Ethical validation is not included in the summary table above, and was added as an additional validity construct in a later iteration of the framework (Walther, Pawley, & Sochacka, 2015). Particularly because there is a significant power disparity between the teachers working in the schools and academics and engineers involved in this project, ethical
considerations became important. The dynamic between the researcher and the participant becomes particularly important in qualitative research and especially when interviewing (Patton, 2002). According to this construct, ethical considerations should be explicit in the research design. The American Educational Research Association provides a framework for such considerations that have guided the following statements. It important to note that this research is funded by the National Science Foundation. The overall study design has been reviewed and approved by our institutional review board, all participants have provided their informed consent, and their identities have been kept confidential. No inappropriate incentives have been offered to coerce stakeholders to participate in this research and the stipend provided to teachers is separate from the research processes and is meant only as an acknowledgement of their programmatic efforts. Participation in the VT PEERS program is not contingent on participation in the research activities. Lastly, although this dissertation is written from a first-person perspective, it is important to note the contributions of the VT PEERS research and programmatic teams. Any publications submitted using this material will acknowledge their intellectual contributions appropriately.

**Validity, reliability, and case study research.** Although their emphasis is on qualitative research quality, Walther et al. (2013) do reference the language traditional in describing quantitative research quality (i.e., construct validity, internal validity, external validity or generalizability, and reliability). This is the language shared by prominent case study methodologists (Yin, 2014). In this section, I will demonstrate the connections to Walther et al. (2013) by explicating the research quality considerations specific to case study research. Yin (2014) suggests that to promote construct validity, multiple sources of data should be used. This was the circumstance in this study as both pre-year and post-year interview transcripts covered the same collaboration constructs. Suggestions for internal validity includes addressing rival explanations which has been discussed in the collaborative validation section. Using replication in multiple case studies has been suggested for improving external validity. The cases in this study are different versions of the same collaboration and the cross-case analysis allowed for comparisons to be made. Yin (2014) also suggests using a case study protocol to improve reliability. Although a case study protocol was not explicitly adopted, the research design and steps outlined here overlap with many of the facets of the protocol example provided by Yin (2014) such as explaining data collection procedures.
Summary

The purpose of this research is to contribute to a better understanding of how interorganizational relationships centered around K-12 STEM evolve in initial stages of development and the implications for future collaborative success. Informed by frameworks of collaboration from Gray (1989) and Thomson et al. (2007), I conducted a multiple case study design to investigate the evolution of the first year of a multi-year collaboration involving public school systems and industry partners. This design was appropriate because the contextual conditions in this study are integral to answering the research questions. The phenomenon of collaboration cannot be easily separated from its context, nor should it be. The framework for research quality from Walther et al. (2013) provided a useful guide for ensuring that specific strategies were planned in detailing this case study design in order to promote validity and reliability. Although arguments could certainly be made for changes to the sampling procedures, detailing the justification around case construction is a more fruitful endeavor in case study research (Yin, 2014). Moreover, research performed from the pragmatic perspective should be assessed in relation to what it is trying to achieve. From the top down, this study was designed to advance the research and programmatic goals of the VT PEERS project while simultaneously contributing to the body of knowledge around pre-college engineering education and interorganizational collaboration.
Chapter 4. Findings

Introduction

From Chapter 3, recall that this analysis was structured around the dimensions of collaboration from the theoretical work from Thomson and Perry (2006) and Thomson, Perry, and Miller (2007). These included: governance, administration, organizational autonomy, mutuality, and norms of trust and reciprocity. While the analysis did leave room for some inductive coding, those codes were ultimately integrated into the five dimensions to improve comparability of results and economy of presentation. For instance, many excerpts originally coded as general program outcomes were eventually aligned under mutuality and those coded as impetus to join the collaboration upon summarizing at the stakeholder group level aligned well with either norms of trust and reciprocity, organizational autonomy, or mutuality dimensions. The trade-offs of deductive versus inductive designs were discussed in more detail in Chapter 3.

Recall that the two research questions guiding this study are sequentially designed. To provide evidence towards addressing research question 1, stakeholder perceptions of collaborative processes in the first year of the VT PEERS program are presented for each dimension and for each of the three case sites. To provide evidence towards addressing research question 2, I will support cross-case assertions based on comparison of the cases outlined under research question 1.

Sequential Research Question 1 (Case by Case Analysis): How do stakeholders characterize the collaborative processes in each county-level partnership?

Recall that for each case, the schools share the engineering activities, university partners, and exist in primarily rural communities. At the same time, each case is different because the school systems and companies have different institutional norms and practices. As described in Chapter 3, Cornerstone Industry is an international organization that employs engineers and technicians to produce synthetic fibers, EchoCorp designs and manufactures foams for diverse applications, and Deltax Corporation is an international organization that specializes in materials sciences to produce a diversity of everyday product materials. In total, 76 semi-structured interview transcripts from 49 participants were analyzed for this study.
Case 1: South County and Cornerstone Industry

In case 1, South County participants included two teachers across two schools, two principals, two county administrators, and five Cornerstone employees. Unique for this case, Cornerstone is located in a different county than the school system. In the sections below, stakeholder perceptions of collaborative processes in case 1 have been synthesized and presented across the five dimensions. An overarching summary is provided for each of these dimensions.

Governance: Negotiated process of developing working rules and structures around collaborative participation.

Summary of governance in case 1. The findings around governance in the first year of the VT PEERS program center predominantly on expectations and experiences around information sharing structures. There was agreement between a teacher and industry participant statements that there should be regular contact between partners to negotiate how to address the collaborative problem facing the group (i.e., bringing quality engineering programming to the science classroom to broaden interest and future participation). Administrators had more contact with the university during the planning stages of the program and were also more comfortable with the structure and decision making than other participants.

South County teachers. Both teachers expressed that they felt the information sharing structure was lacking at the start of the program. There were also some initial thoughts about the logistical requirements of the program that did not align with the program organization proposed by the university affiliates at the introductory workshop. For example, one teacher said that they would need to set aside time regularly to meet with other partners. The teacher explained,

We're gonna have to collaborate with the other teachers in the county. Each school is different in it's own way, in it's own running, in it's own population, and what works in mine may not work in the next one. So, we definitely are gonna have to meet with the teachers to get a consensus of what's working and what's not gonna work. And, let's see. Then, again, with the industry, I think we're gonna have to meet with them and see what they think about it, see what they suggest. And, of course, Tech's gonna be the one driving it, so you know you're gonna be meeting with them. (South County Teacher)

While generally the teacher participants professed to be more comfortable with information sharing structure at the end of the year, there was still some trepidation in their statements.
South County administrators. Administrators were engaged before the other school partners and had opportunity to discuss their thoughts with the university affiliates. Administrators were satisfied with handing over control of the program governance to the university as evidenced by comments on the smoothness of program operation. However, one principal allowed themselves the room to take teacher and student feedback to ostensibly revisit planning if necessary. A county administrator also placed themselves in a mediator position between the county schools and the university to negotiate in the initial stages.

Cornerstone Industry. Industry perceptions around program governance can be categorized in two groups. Participants that had a higher level of involvement in the classroom interventions discussed governance differently than those that participated only occasionally. This first group of participants felt that the structure of information sharing and distribution of responsibility to industry were reasonable. The higher involvement group was more critical of the process and structure. For example, one participant suggested that an upfront investment of time including regular meetings with teachers each month would be best for ultimate success. They stated they were “certainly willing to meet or speak with the teachers in advance of the monthly day in each school.” Please recall that one of the teachers from this county suggested something similar at the start of the program. There was uncertainty about what the costs to industry would be and an expressed desire to clarify. At the end of the year, another industry participant from this group felt that the structure of the class lessons was inadequate for the amount of content planned. These groupings were not a perfect division; one highly involved participant stated that aspects of the information sharing structure were inadequate as established at the start, but took personal responsibility for other challenges faced at the end of year interview and was generally positive about the experience.

University affiliates on governance in case 1. The overarching governance structure was established by university affiliates in the early stages of the program through initial conversations with county administrators, industry leaders, and through writing the grant proposal. Once the project started, one university affiliate stated that it was particularly efficient to communicate through the hierarchy in South County. Similarly, another university affiliate stated at the end of the year that they were able to get feedback about process from Cornerstone because of the relationship with the highly involved industry participants.
Administration: Implementation and management of governance structures including clarifying operating mechanisms such as participant roles, communication processes, and monitoring.

Summary of administration in case 1. Most participants were initially unsure about operating mechanisms for responsibilities and communication processes, but these emerged through participant experiences in the first year. There was fairly strong consensus among stakeholders that teachers and industry partners embodied a subordinate role to the university affiliates. Additionally, administrators, though mostly adopting a hands-off approach, transferred their overseer role in the school system to the program. Although not a great deal was said about the communication processes clarified through year one, it can be reasonably inferred that having specific individuals as organizational contacts may be important to the stakeholders in the collaboration.

South County teachers. There was initial uncertainty about the roles and responsibilities of the different partners. At the start, teachers thought they might have a larger role in designing and directing the classroom activity. At the end of the project, they instead described themselves as assistants and observer-learners in the classroom, leaving the lead in curriculum and teaching to other partners and the largest role to the university. One teacher was happy with this level of responsibility and stated “I guess I enjoy not being in charge, and getting to observe” but at the same time expressing the thought that this may be below partner expectations asking “if that’s a role.” Similarly, the other teacher felt more confident in the classroom as time went on but still felt what they did in the classroom “wasn't ever as good or anywhere near as good as” the university classroom facilitation.

Discussion of industry responsibilities was not as specific, but they were said to be demonstrating local career opportunities by their physical presence and helping bring explanations of company practices to the 6th grade level of understanding. Beyond clarifying responsibilities, one teacher briefly talked about their view of burgeoning communication processes between partners. They stated they would contact the industry partner in the future but were nonspecific about who or how.

South County administrators. Like the teachers, principals in South County were initially uncertain about their and their partner organization’s responsibilities. Both principals deferred to their teachers for any discussions establishing operating systems for the collaboration. For
example, although one principal was curious if the teacher would be observing or leading, they ultimately stated that the probable preference was to be an observer. Similar to teachers, principals saw the role of the university affiliates as preparing and teaching the lessons, providing all the materials. Unlike the teachers, they also recognized that the university would be collecting research data. In discussing the purpose of the industry partner, administrator views on the matter diverged. While principals said that industry had a smaller role of making connections to their work in the classroom when possible, a county administrator explained that industry had the “most vital role” in the collaboration to spark interests in students. Interestingly, one principal was under the impression at the end of the year that industry had been responsible for providing some funding. From the South County administrator perspective, some systems of communication were also planned or established during the first year of the program. Generally, administrators saw themselves as conduits to process feedback from other school personnel and share information from and for the university.

Cornerstone Industry. Consistent with other partner’s view of their responsibilities, industry saw their role as smaller, mainly supportive, and proving a connection to industry by being in the classroom. Although this was not the university communicated responsibility of the industry partner, it was suggested by one participant at the end of the year that they in fact provide some monetary resources (e.g., buying snap circuits) as an administrator assumed they had done. Again, as with the other partners, the university was seen to have a leading role in organizing logistics and program planning as well as leading the activities while teachers were seen to be more supportive or in charge of behavioral management. Notably, they were situated as the experts on the curriculum and experts on working with students as opposed to the teachers taking on the role of sharing expertise built from experience in their classroom.

University affiliates on administration in case 1. University affiliate interviews confirmed the overseer role that the administrators discussed. One participant saw that principals stopped by during some lessons and observed. It was also clear from the university perspective that key individuals, particularly in industry, were necessary to smooth communication processes absent of traditional organizational hierarchy. This is explained further through findings for the remaining dimensions.
Organizational autonomy: The pull between individual organization and collective interest.

Summary of organizational autonomy in case 1. Few stakeholders made statements about their perceptions of autonomy issues within partner organizations, focusing instead on their own feelings on the process. For school personnel (i.e., teachers and/or administrators), generally speaking, preliminary misgivings gave way to contentment once unknowns became clear. For industry participants, the structure of the work environment provided a situation that made it easier to negotiate organizational and collaborative interests.

South County teachers. Although teachers had some initial concerns that the program would conflict with the demands of their teaching requirements and accountability for the students’ wellbeing, they reported that this nervousness lifted by the end of the year. For example, the two teachers in South County in their respective interviews were originally concerned that early lesson drafts were not age appropriate in content difficulty and that having industry participants in the classroom might cause students unease. At the end of the year, one teacher quipped that having a change to regular programming did not impact the typical day-to-day experience. They said,

I don't care what your lessons are, what your students look like, how many students, it's never the same day. So did they upset the routine? Not really. Was it a common day? Not really. But it was just middle school. (South County Teacher)

The tension between their responsibilities to their teaching post and to the program became a nonissue because change and uncertainty was commonplace in the middle school classroom anyway.

South County administrators. Both school and county administrators shared initial trepidations about maintaining school function while participating in the collaboration. One principal expressed concern about maintaining quality of education for students. They were clear that anyone coming into the school must be a good communicator and not a “boring, monotone speaker.” Extending their role as supervisor and mediator from their school position to the collaboration, as discussed in administration, the same principal shared that a teacher told them they were worried the program activities would take away from time spent on the regular
curriculum. The other school principal echoed and exemplified this concern of fitting in program responsibilities alongside teaching duties when they said,

> You all will just have to tell us what you need from us, because ... You teach, and it's busy. It's going to go from their mind a little bit, because they're doing their thing. They're teaching, they're grading papers, they're making tests, they're herding kids.

(South County Principal)

While these are similar to pre-year comments made by teachers, they were positioned at a macro level looking at the whole school or at the overall job responsibilities by teachers rather than pinpointed areas for potential alarm. Arguably, the teachers are in a better position to articulate any tension between their organizational and collaborative efforts but the project requirement of administrative buy-in makes these principal perceptions salient as well. County administration expressed that staff may have general “apprehension” but ultimately expressed feeling satisfied about any potential autonomy problems as program activities became clearer and were plainly aligned with standards of learning. Likewise, principals seemed appeased as teachers shared positive experiences and with the understanding that the university would take a directive role. One principal stated, “whatever you need from us, just let us know at whatever point. We're looking at you all to have that heavy hand with it…” One qualification to this trend is the concern from the other school principal that future school resourcing may be a problem for sustaining program activities. This is explored further in norms of trust and reciprocity.

*Cornerstone Industry.* According to a highly involved industry participant from Cornerstone, the organization already had a history of volunteerism. Beyond this, the lack of autonomy issues seemed to stem from an organizational philosophy that allows for flexibility in working times. The participant explained,

> We're, if I described us as a loose type company, that's probably right...we're able to fit it in, not let things get too behind. During lunch, answer emails and it works out.

(Cornerstone Industry Participant)

They were also happy with the low amount of preparation time required for the industry partner and some participants expressed personal fulfillment arising from interacting with the school system. Where opinions diverged was whether there was wide acknowledgement of the project within the company or if it was predominantly known to the individuals most involved. While
some said it was becoming known or even that their colleagues had children enrolled in the school system that reported they enjoyed the programming, one participant expressed the feeling that it was not widely recognized. It was a few key individuals that championed their company’s involvement in the program. As a final note, an industry participant shared their view that teachers may think the work takes too much of their time away from their school duties, apparently in touch with the initial teacher reservations around autonomy.

_University affiliates on organizational autonomy in case 1._ In their comments on South County, university affiliates made a few remarks with implications for county administrators’ perceptions of organizational autonomy issues. They reported that the program was spoken of at county-level meetings, however, the excitement and commitment at the county level may not have trickled down to the individual schools which were required by the central office to participate in the program.

_Mutuality: “Beneficial interdependencies” based on either a complimentary exchange of resources or a shared interorganizational mission._

_Summary of mutuality in case 1._ Nearly all stakeholders saw benefits for themselves and each other in the first year of the collaboration in case 1, although these were not always specific. Most notably, both school personnel and industry participants identified the long-term investment in future employees to be a primary benefit for industry. Both the university and industry also saw the reduction of the stigma against manufacturing to be potentially a more immediate benefit to industry. Personal benefits to teachers and individual satisfaction for industry were also identified as possible benefits. Considering the different perceived responsibilities of the various parties discussed in administration, it appears that there was an exchange of resources and benefits among the stakeholders in case 1. However, based on stakeholder comments about university investment in the process, although there was an exchange, it is hard to say there was equity in the perceived costs and benefits for each partner.

_South County teachers._ While teachers stated that the students and schools should and did benefit the most of all involved parties, they also acknowledged partner benefits. Although not described as an explicit exchange of resources, complimentary benefits and expenditure of efforts did occur from the teacher perspective. Teachers stated students benefitted from more review of content before 8th grade SOL testing and more knowledge of career possibilities. They also said that they received improved supplies, more interesting and hands-on curriculum, and
implied professional development benefits in connecting engineering to the classroom and new ways of teaching the same content. From investing their time in the classroom, one teacher explained industry participants were said to benefit in the long run from access to and appreciation of an improved, local workforce. From the teacher’s perspective, local business contacts reported shortcomings in employee skills and investing in future employee skills with students at a young age is of real interest to companies. One teacher explained this viewpoint came from a tour of a local hospital,

…they spent the whole day talking to us and telling us the issues they had, what expectations that they had, and they had problems with attendance, they had problems with attitude. And I guess it was, the work force's problems, and they were putting it back and thinking they were gon' put it back in school to the teachers who could do something about it. (South County Teacher)

Teachers also explained that the university gained research data and work towards their goals of expanding student knowledge and interest in engineering. Interestingly, one teacher was clear that both industry and the university were motivated by the perk of increasing student awareness of engineering.

*South County administrators.* Like teachers, all administrators emphasized that students should benefit first and were more specific about the types of skillsets students would be building, calling them “soft skills” or “high level thinking skills” through exposure to problem-based learning. Both county administrators and principals noted that this was a professional development experience for teachers or a chance for them to observe teaching being modelled. One county administrator said this is “excellent PD” for teachers and that the curriculum also aligns with state problem-based learning goals. Like teachers, administrators saw the university getting research data on and work towards their goal of sparking student interest in the subject matter and industry as investing now to reduce future employee skill gaps.

*Cornerstone Industry.* Compared to other stakeholders in this case and other cases, there was less consensus around mutuality at Cornerstone Industry. One participant said that students were benefitting the most but was nonspecific. Another participant clarified that students were getting exposure to more postgraduate options, including local ones, a learning experience beyond the routine, more knowledge of technical and manufacturing jobs, and access to role
models. Still another stated that industry is getting the most benefit, although this may have been a limitation of the interviewee’s perception of why the interviewer was asking the question, and they were also not very specific. This participant also saw the program work as an extension of their position at the company related to social responsibility. In a similar way, another participant felt that industry gained long-term benefits aligned with their goals of investing now to reap more local, qualified, and educated candidates in their recruitment position in the company.

While it is not certain that there is evidence of strong shared interests, there is at least evidence that industry participants see the benefit to themselves. One highly involved individual commented on why this program is important to them and the potential for mutual interdependencies.

It doesn't start with receiving polymer pellets in a bulk truck or a tank car, and it doesn't end with shipping fiber on a loading dock at the containers, etc. What it really starts with is a journey that involves our customers, our associates, and our community. We don't thrive unless our community does as well. (Cornerstone Industry Participant)

This viewpoint was particularly noteworthy when considering that this company operates some distance from the school county itself. They explained that the distance was immaterial because their workers come from all over geographically, so working in South County was still an investment in future, local workers. This same participant explained that other benefits to industry include more contact with the university as a partner, the potential for reducing the stigma against manufacturing in the community, and the possibility of learning how to better support other volunteer activities at the company. Others added that personal satisfaction came from working with students.

_University affiliates on mutuality in case 1_. University affiliates echoed industry statements that the work was aligned with their goals, and specifically the community engagement piece of individuals’ job descriptions, but beyond that implied it also reduces the stigma of manufacturing. One university affiliate said, “they want the perceptions that their jobs are not like the factory jobs…That these aren't the factory jobs of your grandparents' generation kind of thing.”
Norms of trust and reciprocity: Perceived relative degree of obligation or "I will if you will" and evolving beliefs about partner commitments.

Summary of norms of trust and reciprocity in case 1. Many stakeholders had preconceptions about their partner organizations before the project began. While largely positive for the university, these sometimes took a more critical tone for the school system. Regardless, by the end of the project, most individuals seemed confident in what they expected the other partners to bring to the collaboration. For school system personnel, this meant that the university would be taking on most of the load. For industry, it meant they were comfortable with their small role as long as the other partners continued to fulfill the rest of the program needs with the exception of one particular industry participant that chose to dedicate time and effort beyond expectations.

South County teachers. As previously implied, teachers were initially anxious about the partnership and said they were lacking information. Although exposure to the activities lifted some of these worries, concerns about reciprocal obligations persisted at the end of the year. For example, one teacher was troubled by the idea that there would not be as many university affiliates to help facilitate the activity after the year was over. They said, “to be honest, some of the labs would not be a possibility with just the teacher. You would need extra hands just to facilitate it.” Potentially, the realization that there would not be as much university support moving forward was inconsistent with their expectations of university involvement and their own responsibilities.

South County administrators. Administrator apprehensions lessened after the program activities became clearer. In their interviews, principals made remarks implying that as long as the university bore a high degree of the burden, then they were happy to engage with their part as a school. From one principal’s perspective, they were pleased to see that the university was not overly “needy” as other school intervention partners had been in the past. Similar to the teacher realization that there may not be as many adults in the room in future interventions, the other principal expressed concern about future physical resourcing assuming no university help or that they may not deliver on material promises. It was mentioned in organizational autonomy that this principal wanted the university to have a “heavy hand” in proceedings. Although administrators had never heard of Cornerstone before, they had a high opinion of the university which may have tempered the fear of the unknown and allowed them to commit. Still, one county administrator
wanted to see what the partners would be bringing to the table before letting themselves let go of hesitations.

Cornerstone Industry. Similar to school system personnel, once industry participants learned what the university would be bringing, they felt satisfied with their own requirements. For example, one industry participant stated, “I just didn't know what to expect, but once I was in there, and after talking to…everybody else that was helping, I was like, this is going to be easy.” Also, like school personnel, industry participants also had a high opinion of the university that made it easier to assume partners would make good on their promises. Conversely, before the project began, another participant made strong statements about the shortcomings of rural schools and the low quality of the local workforce they produce. Although there was not explicit evidence that this impacted their perceptions of the partners and their dealings, it was an interesting position of superiority to place themselves in above another partner.

In an instance of going beyond what was expected of them, one participant spent time independently developing a large display for a class period, even going so far as to leverage a business connection for advice, but ultimately decided it would be too large for the classroom and never used it. Although it would be reasonable to assume that investing that much time only to find out their display did not meet classroom needs would be disheartening, this particular participant did not seem discouraged by the experience and, if anything, appeared more committed to the organizational relationship.

University affiliates on the norms dimension in case 1. University affiliates have worked with both Cornerstone and South County before and so had reasonable expectations of positive experiences. Despite this, one university affiliate stated that they assumed that issues in production or shipping will supersede any collaborative obligation for Cornerstone. Comments were also made about the significant distance between the county and the company, suggesting this impacts the dynamic between teachers and industry because they had no existing relationship or contact. Other partners mentioned the university taking on the majority of the burden. While this was not ideal for university affiliates, a scaffolded approach to reducing their involvement is consistent with planning mentioned in the cross-case analysis.

Case 2: Springfield County and EchoCorp

In case 2, Springfield County participants included four teachers across two schools, two principals, three county administrators, and seven EchoCorp employees. In the sections below,
stakeholder perceptions of collaborative processes in case 2 have been synthesized and presented across the five dimensions. An overarching summary is provided for each of these dimensions.

**Governance:** Negotiated process of developing working rules and structures around collaborative participation.

*Summary of governance in case 2.* Principals and industry participants were more critical of governance in year one than teachers and county administrators. Teachers qualified their statements of satisfaction based on the prerequisite of adequate university involvement. Several participants across groups acknowledged to some degree the negotiated nature of year one, most notably a county administrator and the senior manager of EchoCorp.

*Springfield County teachers.* At the start, teachers seemed generally satisfied with the structure of information sharing established by the university even though there was evidence they were told they had to participate. For example, one teacher noted the “open communication” and another stated the university contact “stays in communication with us to let us know what's happening.” Even when a teacher saw evidence of only a few lessons being aligned with the standards they teach, they stated that they were confident that university-produced lessons would align saying, “I think the lesson plans will be able to tie in with our curriculum.” Based on their experience in pre-project conversations, teachers discussed how they provided the university with some preliminary information about scheduling and curriculum. Despite these positive comments, little was said about the rules and structures of the program when prompted and post-year interviews revealed teachers did not always feel included in the information-sharing system. For example, a teacher stated “I was really out of that loop, unless for telling them what topic.” At the end of the first year, two teachers were clear that as long as they maintained some of the support structures from the university, they were happy moving forward more independently. For example, one teacher stated “I'd probably venture out on my own more if I knew that if I needed something, I needed help, or I needed assistance, that open line is still there for me to contact” and another explained that as long as the university brought supplies they could proceed, saying “I actually am looking forward to doing some of those lessons with them, and putting my own spin on it.” Notably, when asked if they had any critical comments about the first year, another teacher embraced the notion that collaborative work is a negotiated process over time. They explained,
Well, being the first year you're going to have lots of wrinkles and lots of bumps that you got to smooth out. And that's expected. I didn't expect the first two or three lessons to be smooth, right? Because it's brand new. So I came in with just this accepting attitude, "Hey, we're going to take it and go with it and see what we can build on.” (Springfield County Teacher)

This individual teacher’s attitude did not necessarily represent the attitudes of all the teachers involved in the program during year one but is shared here as a notable contrast to the two teachers who made forward looking comments, but hedged their statements with specific qualifications to their participation (e.g., university bringing supplies or being a line of support).

*Springfield County administrators.* There was a divide in viewpoints between school principals and their county level counterparts around governance. From the start, principals seemed unsure what to expect. For example, one principal had a number of questions they wanted answered, including,

What are the expectations of the university and the business? What do you hope to glean out of this experience? Is this the only time this particular project has been done? Has it been done in other places and what were the takeaways from those experiences?

(Springfield County Principal)

At the end of the year, this principal was also dissatisfied with the system for accounting for weather-related cancellations. At the other school, which had two administrators, principals seemed to lack information and participation in setting up the structure because they were not invited by the county administrators to the initial university pitch and high-level planning session due to a clerical oversight. At this same school, there was some confusion about which of them should be most involved in the program. At the end of the year, school principals across schools reiterated that they still wish they knew more at the start of the project and one felt that they could not fulfill their duties in supporting teachers because of the inadequacy of information sharing structures. For instance, when prompted to offer constructive criticism, a participant explained,

…I was just kind of getting all of this second hand from our staff. So I think you know even if we were just copied down…I love teachers but sometimes they misinterpret things. So that would help me say “well actually I believe they meant this or I have talked
to so and so and corrected that.” So my only thought I can think to do this better would be to communicate better from both sides. (Springfield County Principal)

The school vice principal noting that there needed to be better communication on “both sides” was referring to the university and themselves.

In contrast to school administrators, the county administrators appeared less affected by the uncertainty permeating the start of the project. Like the unique teacher discussed, one county administrator discussed the project as a process of learning as you go. They stated,

I think by the end of the year kind of what I heard was it was more teachers were embracing it, and kind of enjoyed it, and kind of got comfortable with it…I felt like that by the end of the year that was kind of the groundwork had been laid…(Springfield County Administrator)

EchoCorp. Programmatic structures were a point of critique for many industry participants in this case. For example, some statements included feeling uncertain of what they can do to help, concerns of not having enough lead time to plan ahead, uncertainty about their responsibilities, and that curriculum was not aligned with their field. One took comfort with the university’s control over the project and another felt better about the program after seeing several classroom sessions unfold.

One difference of opinion came from the senior manager of EchoCorp who described the first year as an exploratory experience, similar to comments from one teacher and county administrator. They said, “I assume that next year will probably be better and smoother than this year; we are just feeling everything out.” In the same interview, they explained that they joined the project in part because of their personal relationship with an investigator at the university. As with other stakeholders that felt better about the collaborative structures as long as the university maintained a certain level of responsibility, this participant may have been influenced to a more understanding opinion of the nature of year one.

University affiliates on governance in case 2. Unique to the partnership with Springfield County, one university affiliate was unsure exactly who of the many people at the central administrative office they would be working with from the start and that the efficiency of talking down the hierarchy in South County was not found in Springfield County. Another university affiliate shared that they asked less of EchoCorp than others and implied that they intentionally
provided them just basic information ahead of lessons. The same university affiliate stated that principals had a choice to opt in to the program. Although it is clear that principals did have this autonomy to reject involving their school in the program based on the fact that one school in Springfield opted out, it is also clear from principal conversations that some of them felt excluded from preliminary decision-making.

*Administration: Implementation and management of governance structures including clarifying operating mechanisms such as participant roles, communication processes, and monitoring.*

*Summary of administration in case 2.* School personnel sometimes discussed industry participant and university affiliate responsibilities at the same time, grouping them together. Neither school personnel nor industry had a strong idea how to communicate with each other. While teachers were considering this in terms of contacting industry without university help, industry may have been focused on how to provide teacher feedback on expectations. Like in case 1, administrators saw themselves serving in a monitoring, overseeing capacity but were potentially unsure about what other stakeholders should be doing. Both teachers and industry participants saw their role as secondary or supportive of what the university was doing but seemed to find value in their respective role based on their comments.

*Springfield County teachers.* At the start of the project, most teachers saw their role as providing limited insight into the curricular aspects of the project such as objectives and also as supportive to the university as another adult volunteer in the room. One teacher, although essentially agreeing with others, seemed more confident in their role as having veto power over certain aspects and noted if they had more information they could help weave it into a bigger plan. They wanted to be “the person that says yeah maybe this can work, maybe this won't work.” Although some teachers announced greater ambitions for their role at the start, by the end of the year, they had stated complacency with their supportive role, some even arguing it is the best use of their efforts. They self-described as assistants, classroom managers, and offering some curricular feedback ahead of time. One teacher explained they stepped back from the spotlight and let the university lead because they did not want too many competing adult voices in the room. This same teacher discussed how the partner organization did not know much about classroom management, so their role as behavior manager was important, and more than one teacher talked about how getting the students used to the format was a process over time. At least
one teacher thought their newness to teaching would be a barrier to their participation but ultimately felt that concern subside. They said, “I'm a new teacher, I'm not gonna have any input, I'm not gonna have anything to say, and we had great discussions.”

The university and industry roles were often talked about together by teacher participants. Teachers initially said their partners brought the curricular ideas and resources, specific engineering knowledge, or that they were unsure what to expect of them. A teacher explained, "I'm not 100 percent sure. I know they will come up with lesson plans, and give them to us... that we will implement the lesson together…” In the post-year interviews, the responses were more nuanced and the roles clearer. Teachers said the university designed the curriculum and lead delivery and that industry participants brought the practical connection to the classroom lesson, sometimes with physical objects, or were teaching assistants during the lesson. One teacher made the statement that the university was “100% running the activity” and prompted industry to speak in the room.

In consideration of partner communication processes, while most said they would be comfortable reaching out to industry on their own at the end of the year, many said that they would not know where to start, who to ask, or would rather go through the university. One teacher noted that a different industry participant came to the classroom each month and so it was difficult to know who to contact.

*Springfield County administrators.* Both at the start and end of the first year, principals discussed their role as both supportive and evaluative of teachers (e.g., observing them in the classroom and giving them feedback). One principal was hopeful that the university would show them how to provide better feedback as an administrator. Some administrators were still unsure about partner roles when the year was done. Many administrators also professed the desire to have been more involved in the collaboration.

Principals said that the university had a leading, organizing role and were there to guide teachers in this new professional development experience and bring resources and expertise. As with some teachers, there was uncertainty about what industry would be bringing to the classroom, and they were talked about together with the university as bringing an out-of-classroom connection. For example, a principal made the specific comment that the partners will show students how their school skills apply to postschool jobs, making connections between education and career.
County administrators saw their own role as overseeing the overall process and initially pitching the project to principals as a “sales person” for the program. Notably, this county administrator saw the university role to be to represent the college pathway and the industry role to represent the noncollege career pathway. Another county administrator saw the university as a conduit to accessing the industry partner as a school county and to improving the curriculum so that it more closely matches job skills that are needed.

*EchoCorp.* Industry participants in case 2 saw their responsibilities as mainly assistive to other partners and bringing the real-world, career connections in the classroom. An example provided by a participant was their efforts towards comparing bees to a system of workers. The university affiliate in the room typically prompted the industry participant to speak to the class.

Some industry participants had an overall critical view of teacher responsibilities when compared to how teachers described themselves. They were described as having a small or nonexistent role in the collaboration, mostly organizing groups or setting student behavioral expectations. Recall that setting behavioral expectations was seen as important by at least one teacher in case 2. One industry participant referred to this role as “babysitting” and similar comments were made by others and discussed further in case 2 norms. Other industry participants seemed to have a greater appreciation for the perceived teacher role, saying they were a bridge between the university and the student or setting the foundation for students before the lesson day. It is worth mentioning that although industry participants had these teacher critiques, they may not have felt they had the established communication processes through which to share them. For example, when asked about responsibilities of different involved parties, an industry participant talked about how they felt that a teacher should not have left the university and industry alone in the room in a rowdy afternoon session but said, “I don't know how you address that without hurting somebody's feelings or something.”

Like many other stakeholder groups, industry saw the university as “running the show” in the role of leader in setting the agenda, facilitating the lesson, handling logistics, and filling the teacher knowledge gap. More than one industry participant acknowledged that the university was also there to collect research data.

Again, the senior manager had a slightly different perspective on administration. They saw the role of industry mainly to be there the day of the lesson, their physical presence as a real-
world example of the lesson content but they were not invested in student success in the same way as other partners.

We just show up and we are aides, the real-world presence for lack of anything else, I don't feel like there is a lot I contribute other than actual work force and the labor and, hopefully, a good attitude for the class. The success probably matters more for Virginia Tech and the science teacher than it does for me. I'm just a help. (EchoCorp Industry participant)

They saw their own role as coordinating all the volunteers from EchoCorp, and in a monitoring, overseer position like county administration. They said they would make sure industry volunteers were enthusiastic about the process and would intervene if they were not.

*University affiliates on administration in case 2.* Those university affiliates that discussed case 2 in their interviews echoed principal suggestions that Springfield County communication processes are disorganized. A university affiliate gave the example that at an end of the year meeting with county administration, there were new faces in the room who seemed involved with the project but had yet to interface with the university team. Still talking about the school system, another university affiliate that had frequent contact with the industry partners said that they had to work harder to build relationships in Springfield County because there was poor communication even between teachers in the same schools.

*Organizational autonomy: The pull between individual organization and collective interest.*

*Summary of organizational autonomy in case 2.* While school personnel were most concerned about capacity to integrate hands-on activities in the classroom and with the uncertainty involved in bringing outside influence into the school environment, employees at EchoCorp had to make up missed work on their own time. The university saw EchoCorp as a company that has little capacity to address internal crises while contributing to the collaboration.

*Springfield County teachers.* From the start, all but one teacher in Springfield County stated concern about the time and space required to do hands-on activities, as well as potential classroom management issues. For instance, one teacher felt worried about how classroom management would work out when students were “free to move around” but felt more comfortable as the year progressed. At the end of the year, another teacher was relieved of some
concerns of missing out on class time, which was recently cut back for science, when seeing the SOL connection. They said,

And when you know that you're going to be losing a day every month in the end it seems to scare you because you're like, "Oh, I really need that time to make sure" ... But when they brought in all those activities and then it somehow hit on something we had either learned or are going to learn, it made it so much better. (Springfield County Teacher).

Yet, another was more critical of the process at the end of the year saying that there was too much content packed into the period and vocabulary in lessons was above the 6th grade level. Interestingly, this individual changed their more positive tone from the initial interview.

*Springfield County administrators.* Principals’ main concerns from the start of the project centered around the generally overwhelming nature of being short on time and capacity for new things. A few interesting remarks related to organizational autonomy from principals are worth noting here. A vice principal that works closely and regularly with the teachers involved in the program was concerned about “the inundation” of teachers with too much outside support and the likelihood of reverting back to more routinized ways of being. However, they tempered this comment by saying that because science SOL scores have been high from their county, these teachers traditionally miss out on professional development and so this aligns well with an area of need. This same school administrator said that there are concerns of maintaining school order whenever outsiders come into the building. They explained, “sometimes when we bring in outside things, there's always that risk of are they going to be appropriate? Are they going to manage the kids well? Are they gonna get along with the teachers?” Citing similar outsider concerns, the principal of a different school was worried that letting non-school partners see what goes on at the school might give the wrong impression and damage reputation. They said, “I don't want anyone to ever even think, "Well, no wonder our schools are not doing well in science," that kind of stuff.” This comment was aimed at industry participants who were not “educators” like the university affiliates. Although county administrators had less to say about autonomy, both principals and county administrators talked about the potential hesitance of teachers approaching hands-on type things or material they are not familiar with, instead usually falling back to what they know.
EchoCorp. There were some conflicting responses about the impact of volunteerism and the program within the company. Some said it was well known (e.g., a participant was stopped and asked by others at the company what it was all about) and that volunteerism is part of the company mission, while others said it was not well known, and that this is really the first endeavor of its kind at EchoCorp. Based on participant comments, taking time off required a personal interest on the part of the employee and counts as regular working hours. They were expected to still get their work done without accommodations. As an example of how some participants managed this for themselves, a comparatively more involved individual used their regular half days on Fridays. For another industry participant, those same sessions were more challenging because Friday was usually designated for catching up and completing paperwork. They had to shift their working schedule to accommodate both collaborative and organizational tasks. They would do it again, but a lot was put on the individual to negotiate their time to make it work; according to them, an individual has to really want to do it. They discussed the work they were doing as obligation,

I look at it as ... I treat it like my job. I'm doing this ... Our boss asked us if we were interested and I agree that I was interested and he said, "You can do it, or you don't." And I certainly wasn't doing it as a way to get out of working. It was something that we're very busy currently. But it seemed like a worthwhile opportunity for me to get some experience in something I didn't have experience doing. I didn't have to take any time off. It was as simple as ... I came back. I think we got out at 3:00 so I came back and worked for a few more hours at the end of the day, but other than that. (EchoCorp industry participant)

It appeared individuals had to be personally motivated to make accommodations to participate in the project.

For the senior manager, the business had strong personal meaning. They were concerned that employees may resent having to take the time off but make up their work as described. Like many other industry participants interviewed at EchoCorp, they thought the program was an important commitment, even referring to it as paying forward inspiration they received in school, but still recognized that it was a potential negative that they still have to pay their employees for doing this volunteer activity.
University affiliates on organizational autonomy in case 2. It was clear from the university perspective that EchoCorp did not have the same formal mechanisms for outreach activities as other partner companies, despite the fact the one industry participant from EchoCorp claimed volunteerism as part of their mission. More than one university affiliate pointed out that unlike at Cornerstone or Deltax, there was no one at EchoCorp whose job it was to accommodate outreach requirements, that EchoCorp was a comparatively smaller company, and had less capacity to deal with internal crises and continue to volunteer simultaneously.

Mutuality: “Beneficial interdependencies” based on either a complimentary exchange of resources or a shared interorganizational mission.

Summary of mutuality in case 2. All partners emphasized student and teacher benefits, although some teachers were more critical of possible student outcomes. Long-term results for industry discussed by school personnel were not echoed by EchoCorp participants. Some EchoCorp employees reported satisfaction of having community impact, and this was what the university perceived about EchoCorp, but the senior manager said that there were no business benefits to the company from collaborating in this way. Partners talked about university benefits around research and programmatic goals. When compared to statements made about the relative contribution of each party, discussed in administration, from the school and university perspective it makes sense that they stand the most to gain. From the industry perspective, however, schools gained a disproportionate amount to their contribution to the collaborative exchange.

Springfield County teachers. The initial response from teachers was that everyone benefits from the collaboration but particularly students. It was clear that teachers thought students should in fact be the primary beneficiary. For example, one teacher said “obviously the answer should be the student” when prompted to explain who benefits. Students were said to be getting a unique learning experience and real-life connections. Teachers also spoke of their own benefits as a professional development experience that gave them new teaching ideas for engineering and materials. The university and industry were situated as outside experts that could provide more for students than the teacher could alone. Also in the initial conversations, two teachers briefly talked about benefits for the university and industry including stating that they were able to see how the education system works, have an experience in the classroom, and get
involved in the community. They were not specific as to how these things in particular benefitted their partners.

At the end of the year, teachers again said that everyone benefits and were unsurprisingly able to be more specific. Students were said to benefit from a better connection between science as a school subject and science out in the world. They also saw a variety of learners engaged with the hands-on portion of the activities and a reduction in the fear of failure among students. However, some commented that those students already interested in science or engineering benefitted the most. Again, teachers described the program as professional development for them and said they benefit from getting new resources and the chance to observe their students while the university facilitated. While many teachers talked about positive learning outcomes related to science, engineering, and careers for both teachers and students, two were also critical in their explanations. As an example, one teacher said students were “just having fun” and implied less learning occurred. They added that more assessment was needed and any engineering learning would have been subconsciously absorbed if absorbed at all. Another teacher described a lesson in which the instructions were unclear and the lesson fell short of potential. Ultimately, it should be noted that more than one teacher suggested that students were probably still unclear about what engineering was.

Other partner benefits were discussed as well. Although industry was said to be investing in future employees by stimulating interest and increasing needed skills, only two teachers talked more specifically about how other partners benefited at the end of the year. One of them said industry benefitted "minimally" but they did get a chance to show students what happens at EchoCorp, what education level is needed to work there, and garner more community support for their operations. The other teacher explained industry was able to see what went on in schools and have a chance to impact student interest in engineering, essentially describing the personal satisfaction of volunteering as a benefit. The university was said to be meeting their goals of broadening conceptions of engineering careers, improving K-12 education, and using what they learn in that setting to improve the university education.

*Springfield County administrators*. Principals agreed with teachers that students benefit by getting access to everyday life and career connections in their learning as well as more engaging curriculum, and they also agree that they should be the ones benefitting the most. Some also added that teachers were getting a unique professional development experience in designing
hands-on lessons. One principal also expressed that teachers would not normally have a chance to collaborate amongst themselves. This was consistent with the university affiliate view that the teachers do not discuss curriculum much amongst themselves, as mentioned in administration. Perceptions did not alter much from the start to the end of the year, but principals, like teachers, seemed to be able to be more specific.

When principals talked about the university and industry, they sometimes talked about them together in terms of their benefits and motivations for being involved in the program. These comments were often about investing in future employees or student skills and expanding interest in science. For example, one principal explained industry participants want the long-term result of students seeking noncollege pathways becoming more interested in working for them and of having a societal impact. Another stated that industry sees a skill gap with new hires, particularly from areas of low socio-economic status. Only one school administrator acknowledged that the university is getting research data about teaching engineering to middle school.

County administrators viewed benefits from a broader perspective. For example, one saw reducing disconnect or “silos” between college, school, and industry as a shared benefit among partners. Similarly, they added that this program aligns with initiatives aimed at providing “work based learning experiences” for students and helping them become better decision makers around careers. Student benefits were also talked about but in terms of improving overall curriculum by adding both early preparation for future careers along college and noncollege pathways. Other partner benefits were not discussed in county administrator interviews.

*EchoCorp.* Statements about industry benefits included the satisfaction of having an impact on community and positive marketing for their business. Although the senior manager stated that they like the idea of giving back to the school in a “grass roots” effort to make change and they do acknowledge that it is difficult to find adequate engineering prospects in the area, they were clear that they saw “no long-term business benefits” beyond the adding a “community service” activity to what they do.

Compared to other stakeholders, industry made surprisingly specific statements about partner benefits. To start, there was agreement among industry participants that students benefit from the program. Industry participants made comments about student gains including: having a higher interest in STEM; having access to enjoyable, real-world, hands-on, and locally relevant
activities outside the normal pace of the school curriculum; and even being more prepared for a future engineering career. At least two industry participants saw teachers as benefitting from getting a break from their normal strenuous routine. Recall that industry viewed teachers as having a low level of participation in the classroom activities in Springfield County. Industry also had the most specific comments about university benefits when compared to other stakeholders. Comments about university benefits include: research findings; research funding on student learning, and working towards college readiness goals as well as goals of generating more rural opportunity for success. Notably, they were the only stakeholder group to have a participant recognize that the university gained funding.

*University affiliates on mutuality in case 2.* While some university affiliates maintain that EchoCorp benefits, and identified benefits in this collaboration, others had contrasting viewpoints. As in case 1, one university affiliate implied for case 2 that industry benefits from a reduction in stigma against manufacturing jobs. It was mentioned that at least one employee stated that this work aligned with their mission. A university affiliate echoed this point when they said it “fits their identity” as a company. In contrast to these views expressing industry benefits, a university affiliate with frequent contact with stakeholders was clear that unless EchoCorp established more “bandwidth” to volunteer, they did not see it benefitting them in the short- or long-term. Sitting somewhere in the middle of the extremes is the following view from another individual with frequent contact with stakeholders. They stated that industry think of the program as an endeavor with at least minimal benefits. They imagined industry pragmatically stating, “employees live here, it's good for our image” so why not collaborate. Only one university affiliate made a statement referring to the perceived benefits of other partners besides industry. They said that Springfield County schools saw EchoCorp as potentially providing an internship opportunity for older students in their county.

*Norms of trust and reciprocity: Perceived relative degree of obligation or "I will if you will" and evolving beliefs about partner commitments.*

*Summary of norms of trust and reciprocity in case 2.* School personnel expected a lot from the university and had minimal concerns that they did not meet their obligations except for an administrator comment on safety and communication. Although most teachers were satisfied with their efforts and partner relationships, those that did feel they could have done more rationalized their lesser involvement. In contrast, industry was clear that they felt teachers did not
meet their expectations of participation in the collaboration and the university as having to pick up the slack from the school partners. EchoCorp saw their participation in the program as an obligation to a charitable endeavor. The university affiliates said EchoCorp’s involvement would not meet expectations if an internal emergency came up and that no prior knowledge of the industry made relationship building more difficult.

*Springfield County teachers.* With exception, teachers in Springfield County did not seem to think that their primarily supportive role was less than what was expected of them by the other partners. One teacher states, “I don't know how they felt, if they were like, "I wish you would get up and do more," I don't think they did. I thought we had a pretty good working relationship.” This “good working relationship” among partners was echoed by another teacher who explained how partners learned over time to play off each other’s cues in the classroom.

…it just kind of evolved over time. I guess you could tell it was, we were all more open to, well I guess we weren't really close before, just more comfortable with asking questions with each other and it kind of became more of a trade off type thing like when you're working with the kids. Just kind of happens naturally. Like somebody would be working with this student and then they go help someone else and someone else just kind of fills in. It just kind of started to flow. (Springfield County Teacher)

The literature’s description of reciprocal obligation among partners was also illustrated in teacher comments. For example, one teacher said they can handle moving ahead on their own with leading activities as long as the university provides them with the expected supplies. Similarly, another teacher explained that if they see information on curriculum in advance of lessons, and get a chance to observe the university in action, then they will participate more fully. Although from the evidence presented it seems that some teachers may have been happy and confident in their supportive role, there was also evidence of low participation being possibly related to confidence in teaching or feeling uninvited to join. One more experienced teacher spoke about why they chose to focus on classroom management. They said,

I pursued it that way because I didn't want too many voices going on, too many adults directing. A lot of times they came in the first day, and I didn't really know what they were going to do, so I let them. I didn't want to get in the way. (Springfield County teacher)
Springfield county also had some newer teachers including a first-year teacher involved in the collaboration that stated concerns that they did not hold up their end of their collaborative obligations. They said, “there have been several times that I felt like I did not keep up my end.”

_**Springfield County administrators.**_ Although there were not many administrator excerpts flagged for the norms dimension, some notable comments were made by the administrators at one of the participating schools in Springfield County. The vice principal made statements about how being left out of the loop of communication may have had repercussions that the university had not considered such as safety and crisis planning. They explained,

Maybe if they could provide us with a schedule of when people will be here and when people won't and I think maybe have to… I'm always thinking about the building as a whole and safety and crisis and I really like to know who is in the building at all times.

(Springfield County Vice Principal)

At the same school, the principal had a personal connection to the university and spoke highly of them, saying “I think they can offer a lot to us.” At the county level, one administrator professed enough faith in the program and their commitment to self-describe as a “sales person” between themselves and the principal as described in the administration section.

_**EchoCorp.**_ As discussed in administration, while some industry participants did have positive things to say about their classroom experiences, several used strong language to suggest that teachers took excessive advantage of partner support. For example, the phrases “standoffish” and “a point of concern” were used to illustrate teacher behavior. An industry participant described one particularly boisterous Friday class in which the teacher left the room. They said it was “a little bit of surprise that the staff didn't stay the whole time” and described how the university affiliate was left alone to lead the class. Describing a similar experience, an industry participant expressed the sentiment that the teacher should have known better than to leave the room. They said, “class can get out of control, teachers know that, I don’t.”

Other comments suggested that the lesson content was not what industry expected. For instance, an industry participant emphasized that they were not a leader in the class and wished that the lessons were more engineering-themed and less life science-themed. Another described how they did not know what to expect from their experience and did not know what to prepare
from the information sent to them via email. They described, “so the first time I wish we were a little more involved but by the third time I think we had ironed out all the kinks.”

There is evidence that EchoCorp saw the collaboration as a commitment they intended to fulfill. Two industry participants said that they have a responsibility to the “next generation” of workers. Moreover, the senior manager was quick to take ultimate responsibility for the conduct of their workers and stated “I am the one who committed us to do everything.” Recall that although some individuals saw value for the company, the senior manager viewed this as a charitable endeavor rather than a collaboration with “no long-term business benefits.” Based on these comments, commitment to the program as a community service project was behind the resource sharing.

*University affiliates on norms in case 2.* As with case 1, university affiliates were clear that they thought that although EchoCorp was an agreed partner, production and shipping concerns supersede collaborative obligations. A university affiliate described the nature of EchoCorp’s involvement as “doing us a favor.” Another university affiliate echoed this point and summarized their perception of the obligatory nature of EchoCorp’s involvement,

I'm not sure they really see this as something that is necessary or even necessarily contributor to their work. I think they see it as a good thing to do. I think some of their employees enjoy it but I also don't know that that's why they work. I don't know that they would use this as a recruiting tool and maybe it's because of their size too. (University Affiliate)

In terms of school system personnel, a university affiliate did not think that the excitement at the county office level had trickled down to invigorate the school. Another described how, as with Cornerstone in case 1, the lack of knowledge of and existing relationship between EchoCorp and Springfield County, possibly due to industry density in the area, negatively impacted the budding relationship dynamic.

**Case 3: New County and Deltax Corporation.**

In case 3, New County participants included three teachers across three schools, three principals, three county administrators, and eight Deltax employees. In the sections below, stakeholder perceptions of collaborative processes in case 3 have been synthesized and presented across the five dimensions. An overarching summary is provided for each of these dimensions.
Governance: Negotiated process of developing working rules and structures around collaborative participation.

Summary of governance in case 3. Like in all cases, governance was one of the least coded constructs. The university had set up much of the program structure before engaging with stakeholders beyond organization leaders. One industry participant appreciated this but there was disagreement about whether program, and specifically information sharing structures, were adequate in year one among Deltax employees. While teachers did not have much to say about information sharing structure, they assumed that the program governance would be similar to past experiences. Their positivity is notable, especially considering they did not have much choice in participating. The STEM Specialist was an important component of their past, positive experiences. Administrators, including the STEM Specialist, saw the “chaos” of year one as a natural part of the process of setting up a program like this. The university said that this case is unique because of the presence of the STEM Specialist and Deltax liaison positions at those organizations.

New County teachers. Compared to teachers in other cases, teachers in New County had less to say about the information sharing structure or other aspects of governance. One teacher assumed that the structure of the collaboration would be similar to what they had done before with the 4-H club. The teacher said, “I'm guessing it's going to be very similar to what I do with them.” Unique to New County and case 3, there is a STEM support specialist built into the county hierarchy that has direct and frequent contact with teachers. This same teacher thought that the collaboration might be similar to work they have done with the specialist. In fact, all three teachers referenced the STEM Specialist or positive experiences with them. A teacher also referenced the introductory workshop as establishing some of the guidelines of their participation such as pulling appropriate SOLs. Although principals told some of their teachers that they were required to participate in the program, one teacher noted that they also wanted to participate because of past positive experiences with the university.

New County administrators. At least one principal recognized that the rules and structures of the first year are a continual negotiation. At the start of the year, this principal said, This is brand new, kind of feeling our way through it, not quite know what to expect but kind of as we go along I think we'll be able to figure out what's working best for the
students and the school and you all and we'll kind of find that happy medium I guess.
(New County Principal)

The county STEM Specialist echoed this statement at the end of the year in describing the negotiated nature of year one. The county specialist explained,

I think there's a degree of ... This is the first year everybody's kind of figuring it out together. And I think there's a degree of everybody understands that this is new. The curriculums are new. Anytime, I think as teachers, we totally understand anything you try new with kids the first time, may not always go smoothly. And there's a degree of chaos that comes with it. (New County STEM Specialist)

While acknowledging this “degree of chaos” in year one, the specialist qualified the statement adding that the structure of curriculum made the lessons seem disconnected. In general, other county administrators were comfortable with the information they received but were less involved than the STEM Specialist. The other two principals acknowledged at the start that they needed to read more about the project and inform themselves, but one was also critical of the information sharing structure, saying that the university needed to provide more. As with the teacher mentioned, one county administrator expected the collaboration to be similar to other collaborative work they have done.

Deltax Corporation participants. Some industry participants thought the structure in place for receiving and distributing information was perfectly adequate while others wish they had more lead time to digest the lessons or offer feedback. At Deltax, there was an industry participant whose job at the company was to orchestrate volunteer opportunities. Notably, this individual was more critical of the program structure. While this program liaison appreciated having curriculum sent over ahead of time to send out to potential volunteers, they wished they had known when each activity was planned. The Deltax liaison said,

I guess if we had that…for the full year in the beginning or something. Then, we could plan for more demonstration stuff or have more suggestions for something the kids could do hands-on and it be relative to not only real world but to the area. (Deltax Corporation Participant)
The liaison was unsure if the volunteers from Deltax were able to provide feedback after they received the lessons in their emails. Like one of the teachers and county administrators, they also acknowledged the “on the fly” nature of year one and were hopeful that moving forward they would have more planning lead time with the addition of the summit. Also discussing feedback structure, another industry participant wished that there was time set aside at the end of each class to debrief about the session. In contrast to many industry statements, one participant commented that they appreciated how much work the university had already put into establishing a program protocol. The industry participant likened it to their own job responsibilities and explained,

…sometimes when you do volunteer events or partnerships, you have a lot of stumbling out of the gate. And for someone making his living on trying to improve efficiency and better ways of doing stuff, continuous improvement, it was nice to see that there had already been a lot of thought put into it and good execution. (Deltax Corporation Participant)

University affiliates on governance in case 3. University affiliate statements centered around key individuals in case 3. A university affiliate explained that, unique to the program structure in case 3, the county STEM Specialist co-taught all the lessons. Another university affiliate added that this specialist’s involvement was already routinized at the school and other program aspects fell into place to mirror what was typical in the school. Additionally, a highly involved liaison at Deltax organized all the volunteers and was also a frequent participant in the classroom. These key individuals and their impact will be discussed further in administration.

Administration: Implementation and management of governance structures including clarifying operating mechanisms such as participant roles, communication processes, and monitoring.

Summary of administration in case 3. Both teachers and industry saw their role as assistive to the university that was the leader in preparation and delivery. The Deltax liaison saw a more significant role for teachers including ensuring the curriculum aligned. One university affiliate saw different personalities from Deltax behaving differently in the classroom. There was some confusion in the first year around roles and responsibilities as well as communication. The STEM Specialist and Deltax liaison facilitated communication at their organizations, but some
teachers still said they would prefer to go through the university if contacting industry. Administrators saw their role as supportive or managerial. They talked about partner organizations together, saying they were bringing resources and expertise the school system did not have. Some administrators offloaded responsibility to the STEM Specialist, a key individual as noted by the university and teachers.

**New County teachers.** In the first year, there was still confusion around what different partner roles and responsibilities were and how or when they should be communicating with one another. Over the year, there did seem to be a shift in the comfort level with different partner roles in the program, but teachers still hesitated to describe what they should be doing and what others should be doing. Generally, teachers saw themselves filling an assistant and apprentice role throughout the year. Their stated responsibilities included big picture idea generating, identifying SOLs, and learning more about their teaching by observing sessions. One teacher clarifies that they felt more like an assistant because, although the curriculum development was collaborative, implementation was planned by the university. They said,

This year, I think I was kind of in a sense, more of an assistant towards the process. Definitely I can say we were team members in building up maybe the design process, but when it came to the actual instruction, sometimes because we didn't really have the time to sit down and...collaborate, and say, "This is what we're going to do." We were getting lesson plans there. (New County Teacher)

The teachers viewed the university team as the leaders in the process and industry as connecting the curriculum to the company and engineering in the classroom. One teacher explained,

Well, I guess with Virginia Tech, they're going to be the driving force that says, "Okay, this is what we're trying to accomplish." I think with Deltax, what they need to do is drive on the engineering aspects, and relate it back to their company, and how educational, what we're doing here in everyday life, the things that they are problem solving with, how that relates to Deltax. (New County Teacher)

While some were comfortable reaching out directly to the industry partner for support, others said they would prefer to go through the university. Two of the teachers expressed no anxieties
about reaching out to the industry partner. Although, one teacher stated that they would be more comfortable going through the university affiliate.

New County administrators. Like many other administrators discussed so far, principals in New County saw their role as mainly supportive and managerial throughout the year. Although their views did not change much over the year, they did add more detail to what they clarified as their responsibilities at the end of the year. One principal said they wish they had been more involved because they have a responsibility to their school and personnel. This will be explained further in organization autonomy. They said that ideally they would be “someone who would pop-in and be a liaison between the University, and the classroom teacher, and then the students.” Note that they talked about getting feedback from students as part of the desired responsibilities to the program, something that teachers did not mention. Although both teachers and administrators saw student benefits as discussed in mutuality, only principals included students in the communication network.

Two county administrators saw their responsibilities at a higher level, including in the role of information gatherer and disseminator, on-boarder, and connecter to principal instructional plans. However, they also admitted very little involvement beyond initially setting up the program with the university. The STEM Specialist saw themselves in a more hands-on role such as being an assistant in the classroom, a resource to teachers, and a liaison between parties.

As in case 2, the role of Deltax and the university were sometimes talked about together. They were said to bring perspectives and resources that the schools would not otherwise have access to (e.g, making real-world connections to engineering and bringing in people and materials). Two county administrators did not comment much on partner roles other than to say they provided resources. At the end of the year, one county administrator said that industry could help incorporate lessons across the year into a grand scheme.

The STEM Specialist was more explicit and talked about industry as the engineering experts. They said the relationship has grown over the year, especially thanks to the Deltax liaison. One county administrator explained that they thought although teachers were the ones developing lessons and focusing on engagement, the STEM Specialist had a better idea of what teachers were actually doing. A principal offloaded to the STEM Specialist in a similar manner,
citing their preexisting relationships with the partners as evidence that communication was better funneled through the Specialist.

**Deltax Corporation participants.** Like the teachers, Deltax participants saw their role in the classroom become assistive and supportive. In this assistive role, three participants specified that they saw it as their responsibility to provide the real-world context or practical example much like how teachers saw the role of the industry to connect to the lesson (e.g., cost estimating and filtration). Some expressed that they wished their role was larger in the program. For example, one Deltax participant emphasized that their role was “not a big role” and that they did not have much to share for lesson planning feedback because the university did a good job designing. Another participant actually changed their mind from the start of the year and said they were more of a participant in the classroom than anything else and that they did not really help with planning. They said, “I'm a participant. I don't design anything.” In contrast, in their first interview they said that their main role is to help teachers integrate industry context into the lesson. Some industry employees did talk about being engaged with the students in the classroom (e.g., “I was part of the group, coaching along”). Mentioned previously, one particular participant identified as the go-between or liaison from Deltax to the partners. They are not a manager and other volunteers are actually their direct supervisor, but their role in the company is to lead an outreach group and get volunteers. Their counterpart at the school system would appear to be the STEM Specialist and these two positions make case 3 unique.

Industry described teacher duties unfolding similarly to how they saw their own role, as assistive to the university in the classroom. Many saw the teachers’ role as being primarily about classroom management and student engagement. Notably, one industry participant changed their view of the teacher’s role from the start to the end of the year. At first, they thought that they could be primarily concerned with behavioral management. At the end of the year, although they still saw the teacher role as “maintaining the class in order” they also called them a leader in the classroom. Others echoed the former idea by saying everything turned over to university control once that team arrived. Two participants thought the teachers did some introductory teaching for students ahead of the classroom session. The Deltax liaison had a more nuanced view of the teachers’ role and it should be noted that they were one of the most involved of all the industry participants. They said that the teacher made sure the curriculum aligned with their classroom practice and objectives and supported students and volunteers in the classroom. Like the
teachers, Deltax participants saw the university as having a leading role in both facilitation and curriculum development.

_University affiliates on administration in case 3_. University comments emphasized their interactions with individuals. A university affiliate noticed in their observations of the classroom that some Deltax participants stood on the margins and waited to be involved while others engaged continuously with facilitation of the activity. Key individuals and their role in facilitating communication were brought up including the STEM Specialist and the Deltax liaison. In many cases, planning involved communicating directly with these individuals. A university affiliate noted that the STEM Specialist in particular introduced the university to new people and helped provide continuity in partnership as change occurred such as personnel shifts.

Organizational autonomy: The pull between individual organization and collective interest.

_Summary of organizational autonomy in case 3_. Both teachers and administrators held initial concerns around the constraints of the school environment and workload when considering the work and dedication that the collaboration would require. Similarly, there was concern from Deltax employees about the amount of time that preparation and classroom activities would take away from their work. Evidence suggests it was more or less difficult to participate depending on the participant’s position in the company. Although the company has recommended volunteer hours, working time still has to be prioritized on an individual level.

_New County teachers_. There were not many teacher statements with relevance for the organizational autonomy dimension in case 2. One teacher did make explicit comments about being worried that the program work would be an unreasonable amount on top of their regular school duties. They said, “I was really hesitant to actually have the University coming in. I've done the visitor program through the University before, and walked out of there with a numerous amount of work to pile up on me.” They allude to a previous experience with the University that was less favorable for them. This is discussed further in the norms dimension. Another remarked on how the constraints of the classroom and school building, and noisiness of hands-on activities conflicted with other teachers trying to prepare their students for benchmarking examinations.

_New County administrators_. Principals talked about time management issues and concerns over disruption to routine. One noted that this did not end up being reality, saying “Initially, our concerns were scheduling and how this was ... was this gonna be disruptive to the
learning environment that was already going on, and the standards. And it's been everything but that.” However, despite this commentary on the lack of tension between classroom goals and program agenda, they also discussed that the reason they were not able to fulfill their perceived responsibilities was due to the constraints of their administrative job. They said,

Well, to be honest with you, I'm not as pleased with the role that I played this year, because I felt like I wasn't as involved as I could have been in the process. And it's not because of the way that I wanted it to happen, it's just the time constraints of being the only administrator in a school that is 500 strong. So obligations here and there, I've been pulled and stretched quite a bit. (New County Principal)

Speaking at the start of the year, another principal said that although maintaining their school agenda and program agenda was a challenge, the program could be made to work with the school schedule. They explained,

Just the only thing I can think of would be coordination of schedules. Certainly, we are within a tight timeframe. We're scheduled, you know, we have certain things, curriculum that we have to cover. And, we have, not only a specific classroom schedule to think about, but basically the entire school because it's a domino effect. You move one thing; it changes other things such as lab times, library times. But, I think that would be the biggest challenge. Not necessarily, you know, a negative effect but it might be a challenge. But, I'm sure something we can work with. (New County Principal)

The county administrators did not seem to be concerned about time and held the university and Deltax in high regard. The STEM Specialist, however, said they are concerned about access to materials in the future and setting up teachers for failure if it is up to them to get them moving forward. They also noted it was hard for teachers to really understand the lesson and give feedback until they saw it modelled. The STEM Specialist went on to say that the day-to-day classroom environment is very busy and that it was hard for teachers to sit down and process something like the lessons shared with them from the university, especially if they feel they do not know what they are doing.

_Deltax Corporation participants._ Generally, there was some concern that the program would bring more work to Deltax employees on top of their busy schedules. One participant commented, “I think it's time on our side, on the industry side.” Participants detailed the
volunteerism structure of Deltax. Depending on the position of the person within the company, it was harder or easier to dedicate time to program activities. Operators have to get approval from managers but otherwise employees do not need to use personal time. Every employee has volunteer days they can use like vacation days in place of a regular 8 hour shift. The company goal is for everyone to complete 36 hours per year of community service. They prioritize their working time first, but if nothing comes up then they can commit to volunteer opportunities. Hourly workers have less flexibility than salaried employees and must communicate with supervisors and make up hours. A participant explained how different employees may balance their own work with the program,

   Usually it's just like communication with our supervisor. So if that day that it was, I think it was like up to 2:00 or something like that, I just told my supervisor, hey I'd like to participate in this. And that's okay. So there's certain ... We're allowed so many hours to go during work, and then outside of that it's just our time, right? And so that would be my responsibility to make up those hours. So for me, I'm okay with making up the hours. But for someone else, they may not want to make up those hours and take a day off to go and do this. So a lot of times, it's kind of a mix. Some people like the weekends, some people like the weekdays. Me, because I don't live over here… so I like the weekdays if I'm going to participate over here because I'm over here already. And it doesn't bother me.  
   (Deltax Corporation Participant)

There was concern among Deltax participants about what amount of time would be expected both in preparation and in the classroom. A lead engineer at the company wanted reassurance that the university had an additional partner so that Deltax would not be solely responsible for this commitment and that there would be enough capacity. Another participant was wary until a colleague told them the workload was not overburdening.

Some people at Deltax were known for choosing to participate in community outreach more than others. There was some disagreement about how well known the project was within the company. The reasoning of one participant why any of their volunteerism was possible or why the company cares about what they call stewardship was that the company is in danger if there are not enough employees in the future and they see it as a monitoring of the workforce
rather than a pull against their day-to-day operations. They said, “that's why the company allows us to participate in this kind of activity.”

*University affiliates on organizational autonomy in case 3.* Affiliates made statements about company philosophy. One university affiliate noted that volunteering is a large part of the Deltax mission. Before most of the data collection began, the program had a different industry partner for case site 3 that withdrew from participation in the project. In contrast to their comments about Deltax, this affiliate said the old partner would not have met the program’s personnel needs because of the demands of their grant-based business model. Another university affiliate emphasized this difference when they explained that if Deltax had production issues, they found new volunteers to fill the slots of those made unavailable. This quick reaction and dedication to program needs was in part due to the efforts of the Deltax liaison.

There was one statement relevant to organizational autonomy of the school system. A university affiliate mentioned that because the teachers were used to the idea of the STEM Specialist facilitating special classes for them, they fell easily into a routine with the program classroom sessions, potentially mitigating autonomy concerns.

*Mutuality: “Beneficial interdependencies” based on either a complimentary exchange of resources or a shared interorganizational mission.*

*Summary of mutuality in case 3.* School personnel and industry talked about mutual benefits, including student benefits. Teachers and administrators saw teachers as getting a unique professional development experience, the university meeting outreach goals, and Deltax as both improving their image and investing in future employees. Deltax also mentioned that they are improving their image through involvement with the program.

*New County teachers.* The default comment from teachers when discussing expected benefits and outcomes was that everyone involved would benefit greatly from the process. After the first year, their comments around this became more nuanced. Some comments include that teachers were getting a unique professional development experience, that students had the opportunity to learn more about engineering and its connection to science, the university was potentially drumming up interest for their programming or sparking the interest of future engineers, and the industry partner was investing in their community and potential future employees in the hope that students might see Deltax as a place to work. For example, a teacher detailed,
I think everybody. I think, well I think in the long-term [university affiliate] hopefully will have students interested in engineering. I think the industries are going to benefit from the fact that once they do possibly have students graduate with engineering they may come back and apply. And maybe be interested towards jobs in that area. The students are going to benefit because they're learning more about engineering. And, we're going to benefit because its new instruction, new information that typically we wouldn't have maybe even thought to put in to our classroom. So I think everyone. (New County Teacher)

This teacher repeated a very similar statement about benefits at the end of the year and more than one teacher explained that Deltax was getting recognition and may benefit later as more students stay local and choose to apply to their company. Public recognition and altruistic satisfaction were also cited as potential benefits for Deltax.

New County administrators. As with teachers, administrators did not waver in their ideas of benefits but did sometimes provide more detail in post-year interview responses. Most principals and county administrators said that students and teachers benefit while some simply stated everyone benefits. Students were said to benefit from opportunity and resources they would not otherwise have, while teachers were said to benefit from professional development and new perspectives in the school (e.g., how to teach something abstract like science in a hands-on way). One principal that stated that everyone benefits reasoned that without mutual benefits there is no partnership. A county administrator was less strict in their assessment of partnership and explained that although they thought everyone benefits, students and school rightly benefit the most. Another principal discussing school benefits said that the program includes transferable lessons that can go beyond 6th grade curriculum and increased SOL scores at the school. The same county administrator notes that partnership with Deltax and connecting to engineering careers aligned well with new county career planning initiative.

Although administrators had less to say about partner benefits, one principal did note that the university receives research- and evaluative-type feedback, and more than one principal commented that Deltax was investing in future employees now to reap the benefit later. In discussing long-term industry benefits and their connection to school benefits, a principal said, “industry is benefiting the students, the students are coming out better prepared for the industry, and it just keeps on feeding everybody.”
In a unique statement, a county administrator suggested the benefit of partnering with organizations that are different rather than totally aligned in mission, suggesting the basis of complementarity in collaboration. They reasoned,

There's no reason to collaborate with populations that you are alike. I mean, there may be, but you know what I'm getting at. We need to learn from each other, and I think the only way you can learn from each other is to start at opposite directions with opposite goals. (New County administrator)

_Deltax Corporation participants._ Like other partners, industry participants discussed everyone benefitting and mainly students benefitting. Those who said everyone will benefit talked about Deltax benefits including: developing a better understanding of the school system, student preparation, and student interests; prepping for the next generation of employee and monitoring their workforce; and personal satisfaction of helping the community as well as a break from the regular working routine. Two industry participants said that Deltax was benefitting mainly through the opportunity to manage negative perceptions of the company in the community. A participant hoped that students would see the company as “more than just the smelly plant…that they realize there's a wide array of jobs.” Some participants alluded to Deltax’s community service mission.

In reference to other partners, the common response from Deltax was that students get a unique learning experience, potentially become more excited about engineering and teachers get resources they would not normally have. For one participant, student and school benefits were the measure of project success. They explained,

…after we participate with this school, the students get more of the principles when you're in, you can utilize what they have learned in class to the real-life situations. I think that can be considered as success of this project. Basically give them more hands-on experience to use the principles learned in the class that we ... it's not just a concept in the brain, it's actually something you can put your hands on. (Deltax Corporation participant)

The university was said to benefit from increased “flow of talent” to university and Deltax goals of stewardship and community outreach to be aligned as well as the goals of preparing students to attend the university or to be employed at Deltax in the future. An industry
participant said, “I draw a lot of parallels with what Deltax is trying to do in this community versus what Virginia Tech is.”

University affiliates on mutuality in case 3. When a university affiliate discussed county benefits, they said that this project serves as a vehicle to continue the STEM Specialist’s agenda in the school system and likewise serves as a vehicle for Deltax to meet volunteerism goals. Additionally, more than one university affiliate saw Deltax as benefitting from the opportunity to repair community perceptions of their operations. As an example of some of these negative perceptions, an affiliate said, “the company doesn't necessarily have a good reputation in terms of what they make and that it smells, the plant smells. And it's on the river, so I think there's general concern there.”

Norms of trust and reciprocity: Perceived relative degree of obligation or "I will if you will" and evolving beliefs about partner commitments.

Summary of norms of trust and reciprocity in case 3. Both school personnel and industry were at first wary of what to expect from their partners. Both implicitly and explicitly, stakeholders explained that they felt let down by the information and preparation from the university. Notably, the STEM specialist spoke of relationships being formed in year one. There was also evidence that Deltax employees may have wished to contribute more but were not invited to do so.

New County teachers. At the start, many teachers had concerns around what was expected of them even though some had past positive experiences with the partners. There are examples of this line of thinking in all teacher interviews. A teacher said “my biggest fear is they walk into the classroom and bring out materials and I've never seen it before…I'm going to look like a student but that's okay.” Another teacher, although they had experience collaborating with 4-H before, still said at the start of the year, “I hope that I'll do a good job. I think so.” The third teacher explained at the end of the year that they think other partners wished their involvement was bigger but that they feel like they were not equipped to participate and that their partners would find them lacking. They explained this fear and that it was ultimately unfounded,

…it's a little intimidating to know that you're gonna have science people coming in and you have that fear: oh my gosh, they're gonna know I don't understand the science, and I'm gonna look stupid, and I don't know what's going on, and it totally wouldn't be like that. (New County Teacher)
One teacher had an idea as to why the teachers felt untrusting of the project at first. They suggested that it had to do with their lack of involvement in planning. The teacher explained,

Maybe not felt as comfortable coming in because we hadn't been the major part. We had just shared, "These are our ideas that we want to have incorporated into the classroom. Maybe these are some thoughts that you might want to consider." So when that design team met, they held the pieces of what they felt would be the best, and they put the plan together. (New County Teacher)

In addition to being wary of what other partners might expect from them, they were wary of what to expect from other partners. At the end of the year teachers were pleasantly surprised by the amount of industry participant engagement with students in the classroom activities. One teacher said, “I wasn't really sure how much Deltax would contribute at the beginning. I didn't know if they would just be there and say, "This is what we do." But they were a really active role inside of the classroom.” The interactions with the university became more credible to them over the year as well. One teacher noted that as long as the university delivered on supplies and resources, that they felt okay about the classroom activities commencing. Another teacher explained “once they came in and I saw what they were doing and that lesson was modeled, I was fine with it. I was like, "Oh, okay, yeah." That's what they mean by the language they were using.” University affiliate actions alleviated teacher misgivings. The STEM Specialist, another frequent presence in the room, seemed to be someone that the teachers have worked with frequently before and trust in their classroom. A teacher nicely summed up their experience collaborating. They said,

I think that I've gotten a better understanding of the STEM program and the purpose of a collaboration. At first I think that I was very intimidated, because it's a university that's coming in my classroom. I felt like probably I didn't know as much about it as I should have known as a teacher. But it really was a cooperating partnership. (New County teacher)

New County administrators. Like teachers, administrators had some successful work in the past with partners, but they still were wary of what to expect. Specifically, two principals cited positive experiences working with Deltax in the past. Likewise, one county administrator had a very positive view of all partners dedication to the program from the start. They said, “there seems to be a number of truly invested stakeholders. That was the first thing I thought.
These folks are serious about this.” Another administrator saw the program’s ultimate purpose as to persist beyond the funding period and build lasting relationships.

In some ways, the STEM Specialist, the county administrator most directly involved in implementation, implied being let down by the collaborative partners. They said there was a need to clarify the messaging about engineering and engineering careers in classroom activities. They also felt that teachers would take more ownership if they were more involved in curriculum development. It was positive to them that the curriculum was aligned with state standards but thought maybe the Next Generation Science Standards were overemphasized at the loss of the pertinent SOLs. That being said, they did speak positively about the relationships being formed. They said,

…some of those relationships that we've built, especially with Deltax and especially for the Deltax liaison and I have gone beyond just this project. And with some of the grad students, we had some of the grad students that were involved with VT PEERS come and do the STEMposium. And the Deltax liaison has kind of gotten involved with some of the other things that have been going on. And so those relationships have been initiated and then have kind of grown as the program has grown. (New County STEM Specialist)

Deltax Corporation participants. Among the industry participants, there was a great deal of uncertainty about what different folks would be bringing to the collaboration. One participant in particular did not trust that the school would have the resources (e.g., science or technical background and intensity of courses, supplies such as computers and lab equipment) that they thought might be necessary for the activities. The same participant was concerned about whether the university had done this type of program before and knew what they were doing. From the Deltax liaison, it could be inferred that they felt they were trying hard to meet what they assumed were the expectations by generating volunteers, but they seemed let down by the information they received from the university in preparation. Similarly, another participant thought it would be helpful to do more planning ahead of time. As they went more frequently, and teachers and students started to recognize them, the process was smoother because they were “prepared versus just reacting.”

Some participants made unique comments about the purpose of industry in the collaboration. One suggested that industry was not being utilized enough and that Deltax could
potentially provide more funding. Two others made comments that suggested that the partnership and curriculum development was primarily between the university and teachers and that they were just there as volunteers doing service work. This conflicts with statements made by some school personnel.

*University affiliates on norms in case 3.* Unique to this case, an affiliate stated that teachers do in fact know industry participants by name and have forged a personal relationship they can rely on in the future. Another explains that Deltax had a preexisting relationship with the STEM Specialist and New County through the HeadStart Program, so they are building on existing relationships in this county rather than working from scratch. One university affiliate also corroborated industry statements that they become more comfortable over time. Lastly, a comment made by an affiliate summed up concerns about what happens if Deltax’s desire to be more involved is not addressed by other partners. They said, "if you desire to be committed at a deeper level, and you're not invited to do that, I think that could quickly turn into not feeling very fulfilled in the partnership.”

**Sequential Research Question 2 (Cross-Case Analysis): What collaborative processes emerge across these county-level characterizations within the broader VT PEERS project?**

By merging the individual case findings presented above, I determined 8 salient cross-case assertions about the collaborative processes in year one of the program. The method of aggregating these assertions was driven by techniques described in Stake (2006) and Yin (2014), and the assertions themselves are validated in part by triangulation across cases (Stake, 2006). The most related constructs from Thomson and Perry (2006) and Thomson et al. (2007) are tagged at the end of each assertion, but evidence was drawn from across constructs. For example, some of the governance and administration assertions also draw from evidence from the norms and organizational autonomy dimensions. As mentioned in the introduction, these constructs are not mutually exclusive. The 8 salient cross-case assertions are:

1. While some participants were critical of year one governance, others accepted shortcomings as part of a negotiated process (Governance).
2. With the exception of case 2, specific individuals channeled key collaborative processes (Governance and Administration).
3. Intra- and inter-communication requisite for collaboration, particularly for monitoring and feedback, was lacking (Governance and Administration).

4. Teachers and industry employees, in the process of clarifying their responsibilities, saw their role as supportive of the university role (Administration).

5. Industry investment had to do with both perceived capacity and company philosophy (Organizational Autonomy).

6. Despite enthusiasm to join the program, school personnel emphasized the constraints of the school environment (Organizational Autonomy).

7. There was evidence of a complimentary exchange of benefits and resources, though to different extents, in all three cases. However, there was little equity in this exchange, particularly in case 2 (Mutuality).

8. Although there were some difficulties towards establishing credibility among partners, there was also evidence that participation improved relationships (Norms).

(1) While some participants were critical of year one governance, others accepted shortcomings as part of a negotiated process (Governance). Participant misgivings and critiques of program structure have been described throughout and in these assertions. While many ultimately changed their viewpoints after they saw the program in action, others did not need confirmation of program success to see the collaboration as an emergent process in the first year. Specifically, a teacher and the senior manager at EchoCorp in case 2 and a principal and the STEM specialist in case 3 made comments towards this notion. Using phrases such as “degree of chaos”, “feeling everything out”, “feeling our way through it” to describe year one, these individuals characterized the collaborative experience as one that requires participants to take challenges as they come and clarify unknowns as the year progresses.

(2) With the exception of case 2, specific individuals channeled key collaborative processes (Governance and Administration). In all cases across the program, the programmatic lead from the university was spoken highly of as an important individual to the collaboration. In individual cases, key participants emerged through year one as integral to facilitating collaborative processes. In case 1, this was a few highly involved individuals at Cornerstone industry. They communicated regularly with the university and engaged with teachers in the classroom. In case 3, there was the Deltax liaison and the STEM Specialist for the county. Administrators offloaded some communicative responsibility to the STEM Specialist; they were
an active conduit between teachers and the university and a regular presence in the classroom. Likewise, the Deltax liaison was an advocate and responsible person for the program at the company, communicated regularly with the university, and also participated in the classroom. Based on the frequency that these individuals were mentioned in interviews and overarching university comments about program operation, these people were integral to establishing the program in year one. In contrast, in case 2, in which no such individuals emerged, there was lower consensus in interview statements around partner responsibilities. The university interviews suggest that the county operations are disorganized and that the leadership at EchoCorp, although taking explicit responsibility for their employee’s obligations to the program, did not provide the same program support as the Deltax liaison or leading individuals at Cornerstone. Despite the effort of key individuals, communication processes and information sharing structures were variable and deficient to the detriment of the program, particularly with regard to monitoring protocols as discussed in assertion 3.

(3) Intra- and inter-communication requisite for collaboration, particularly for monitoring and feedback, was lacking (Governance and Administration). There was evidence in all cases that the information sharing structure put in place by the university was insufficient for the needs of the first year of the program. Uncertainty was expected but participants had specific critiques related to communication. For example, an administrator in case 2 did not appreciate getting information second hand from staff and the Deltax liaison in case 3 thought they should have had information about the activities at the start of the year in order to plan their involvement better. Additionally, although many teachers across cases stated they would reach out to partner with industry moving forward, they were unsure how to do so. Some were specific that they would go through the university but there were no explicit conversations about how that would proceed. One university affiliate, speaking about the project as a whole, was critical of the communications that the university set up, saying it is “hard to get people excited and engaged if they don't have the information about what's going on.” They also add that there was minimal communication between partners, and that communication mostly took place between the university and partner organizations.

Even though some administrators and managers saw themselves in an overseeing or monitoring role in the program in year one, there was evidence that formal mechanisms for monitoring and feedback did not emerge. For example, in case 2, industry was very critical of the
teacher role but did not know how to address their concerns. There were teachers in this case under the impression that their actions were sufficient to fulfill their programmatic obligations. In case 1, at the start of the program, both teachers and industry thought that it would be better to establish regular meeting and feedback time but this never came to fruition.

(4) Teachers and industry employees, in the process of clarifying their responsibilities, saw their role as supportive of the university role (Administration). Although initially unsure about what their responsibilities would be, by the end of the year, most teachers and industry employees saw their role as subordinate to the university role of leading curriculum development and delivery. In case 1, where teachers had a more articulated ideas of their role to begin with, the end of the year saw their viewpoints shift to a lower level of involvement. The general uniformity in responses at the end of the year suggests that participants may have adjusted their view of their role based on classroom experiences and conversations. For example, industry was often talked about as bringing the real-world or career connection to the classroom. The assistive role of the teacher in particular may have been by design based on university interviews in order to scaffold responsibilities in year one. A university affiliate described this as a scaling back towards a “consultation” model. Another affiliate speaking about the project as a whole was unsure if this scaffolding plan was communicated to partners or if it was only discussed on the university side of things. Initially a summer conference was planned before the start of the year in order to help establish rapport and communication processes. This affiliate thought that the lack of a conference was used by their peers to rationalize a less collaborative year one for the project.

(5) Industry investment had to do with both perceived capacity and company philosophy (Organizational Autonomy). Although all industry partners ultimately delivered on their promise to engage with the program, it was clear that their participation was interpreted differently depending on the company structure for volunteerism and organizational culture. For instance, Cornerstone in case 1 and Deltax in case 3 both already had established capacity for volunteering and this program in part fulfilled their service objectives. In contrast, EchoCorp did not have a large amount of volunteer or collaborative activity and their interpretation did not extend beyond fulfilling their obligations at an organizational level even though at an individual level, some participants may have found it easy to dedicate themselves further.
The biggest concern for industry participants was balancing making up lost working time with their collaborative efforts. This was more or less of an issue depending on the organization. At Cornerstone, the organizational philosophy allowed for flexibility in getting work done. Similarly, at Deltax, they had a robust corporate structure for volunteering, suggested volunteer hours, and a full-time employee with outreach responsibilities who served as the liaison to the program. At EchoCorp in particular, but to a certain extent at all partner companies, having investment or desire to participate on an individual level was necessary to sustain volunteers. Different workstyles likewise had a variable effect on how much of a pull collaborative responsibility became. At Deltax, although hourly employees generally had less flexibility than salaried, all types of positions allowed individuals to volunteer. Recall that similarly at EchoCorp, one individual had an easier time giving up their Friday work day than another.

(6) Despite enthusiasm to join the program, school personnel emphasized the constraints of the school environment (Organizational Autonomy). Both teachers and administrators across cases cited concerns about the program responsibilities taking away from their first and foremost responsibilities to the school and students. Common examples were about teachers not having enough time to develop or integrate new material or that hands-on activities cause classroom management issues. While generally these concerns were alleviated by seeing the program in action, some individuals still made similar or even new statements around autonomy at the end of the program. There was one unique statement worth mentioning on its own from an administrator in case 2. They said that they were concerned that an already shaky school system reputation may be further tarnished if outsiders come in to volunteer and interpret the science curriculum as lacking.

(7) There was evidence of a complimentary exchange of benefits and resources, though to different extents, in all three cases. However, there was little equity in this exchange, particularly in case 2 (Mutuality). Stakeholders identified a variety of benefits for all those involved in project. These views became more nuanced and solidified over the course of the year. Benefits for students and schools were highlighted by all parties including new learning and exposure opportunities. Some hypothetical long-term benefits for industry were discussed such as reducing the stigma against the manufacturing plant at Deltax and Cornerstone, improving their image as community service providers at EchoCorp, or investing in improving the skills of future employees. Despite this, it was clear that all parties felt that the benefits
mostly went to the school system. In case 2 in particular, the senior manager at EchoCorp said they saw “no long-term industry benefits.” The rhetoric about partnership at many companies, but particularly at EchoCorp, emphasized that industry’s involvement was charity and volunteerism. Both explicit and implicit in industry discussion was the notion that working with the schools was personally meaningful. Although managers may not have discussed it this way, this could have been another long-term benefit for industry. There may be nothing wrong with a service-orientation to collaborating, particularly if all parties are still committed to collaborate out of obligation despite limited benefits like in this study. The university was seen to be benefitting from research and funding and university affiliates state that most of the program resources have gone to research. These findings demonstrate that an uneven exchange of benefits was achieved in year one. The impact of this can be seen through the lens of the norms dimension.

(8) Although there were some difficulties towards establishing credibility among partners, there was also evidence that participation improved relationships (Norms). Without a measure of trust or at least some agreements on the basis of reciprocal exchange, there could be no mutuality in partnership. The VT PEERS collaboration in year one stabilized mostly on the basis of reciprocal obligation (i.e., an organization will do X because they believe their partner will do Y in kind). While there was evidence of credibility being built up among partners over time, there was also consensus of misgivings among partners. With the exception of case 1, stakeholder groups expressed feeling let down by their partners. They said that their partners failed to make good on what they perceived as their implicit or explicit promises to the collaborative effort or implied that they took advantage of an opportunity to contribute less. Most notably, in case 2, industry participants stated repeatedly that they felt that teachers let the university and industry take on too much responsibility for the classroom lessons. The teachers, however, were unaware that they were delivering less than what their partners expressed. For example, a teacher was clear that no one ever said to them “I wish you would get up and do more” and from their perspective, the teamwork was balanced.

More benignly, industry and school personnel in case 2 and case 3 explained they were let down by the university’s communication and pre-session preparations. For instance, an administrator in case 2 who did not know the schedule of the activities was concerned about safety protocols. An industry participant in case 2 stated that lesson content was not as expected
based on what was described. Some of these issues may be cast aside as part of the negotiated nature of year one as described in Assertion 1. For instance, although some industry in case 3 were let down by the timing and content information they received, at least one Deltax employee felt better after participating in multiple sessions.

Despite these bumps in the road to establishing credibility among partners, several stakeholders across cases made it clear that they felt that relationships were being built and there was evidence of stakeholders feeling better about partners meeting obligations and in some cases exceeding them. For example, in case 2, teachers were pleasantly surprised with partner actions in the classroom such as industry engaging with students.

**Summary of cross-case assertions.** I presented 8 cross-case assertions derived from merging the results from the individual cases. From participant responses across cases, it was clear that many recognized that collaboration emerges and develops over the initial stages of a program such as this. This process was facilitated by the actions of key individuals with the exception of case 3 which notably lacked this emergent resource. Despite the effort of these individuals, communication processes and information sharing structures were variable and deficient to the detriment of the program, particularly with regard to monitoring protocols. Additionally, the process of clarifying roles and responsibilities was the process of coming to terms with a subordinate role for school personnel and industry participants and their organizations. An organization’s philosophy and capacity to collaborate with school systems impacted how they perceived autonomy issues. The nature of the school environment meant that there will always be some autonomy concerns. Despite the shortcomings of year one, there was evidence of complimentary exchange, but not on equal terms. The impact of this was evident in participants’ perceptions of their partners’ credibility and willingness or ability to meet obligations.
Chapter 5. Discussion, Implications, and Conclusion

Introduction

In this chapter, I will interpret my findings about the collaborative processes apparent in year one of the program in light of contemporary and historic literature on interorganizational collaborations and pre-college STEM education. In Chapter 4, I determined 8 cross-case assertions by comparing the results from the characterizations of the collaborative processes in each case (refer to Figure 4 for more details). By looking at the evidence supporting the cross-case findings, actively considering intersections, and exploring connections to new literature, I developed discussion points grouped into three categories: an emergent and negotiated process, autonomy and investment, and equity and exchange. Table 7 illustrates how the cross-case assertions map to their most associated discussion points.

Table 7. Mapping cross-case assertions (findings) to discussion points

<table>
<thead>
<tr>
<th>Cross-Case Assertions (Findings)</th>
<th>Discussion</th>
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<tbody>
<tr>
<td>(1) While some participants were critical of year one governance, others accepted shortcomings as part of a negotiated process (Governance).</td>
<td>An Emergent and Negotiated Process (Assertions 1-4)</td>
</tr>
<tr>
<td>(2) With the exception of case 2, specific individuals channeled key collaborative processes (Governance and Administration).</td>
<td></td>
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<tr>
<td>(3) Intra- and inter-communication requisite for collaboration, particularly for monitoring and feedback, was lacking (Governance and Administration).</td>
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<tr>
<td>(4) Teachers and industry employees, in the process of clarifying their responsibilities, saw their role as supportive of the university role (Administration).</td>
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<tr>
<td>(5) Industry investment had to do with both perceived capacity and company philosophy (Organizational Autonomy).</td>
<td>Autonomy and Investment (Assertions 5-7)</td>
</tr>
<tr>
<td>(6) Despite enthusiasm to join the program, school personnel emphasized the constraints of the school environment (Organizational Autonomy).</td>
<td></td>
</tr>
<tr>
<td>(7) There was evidence of a complimentary exchange of benefits and resources, though to different extents, in all three cases. However, there was little equity in this exchange, particularly in case 2 (Mutuality).</td>
<td>Equity and Exchange ( Assertions 7&amp;8)</td>
</tr>
<tr>
<td>(8) Although there were some difficulties towards establishing credibility among partners, there was also evidence that participation improved relationships (Norms).</td>
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Though rooted in the framework used for analysis from Thomson, Perry, & Miller (2007) and the seminal work from Gray (1989), this discussion offers insights into how we may shift our understanding of the collaborative processes involved in school-university-industry partnership. I will also present implications for research, suggest future work, and outline
considerations for practitioners seeking to collaborate. The results have implications for the interorganizational collaboration within this program and beyond, and I present information about how the knowledge of collaborative processes can be leveraged to promote success in partnership.

**An Emergent and Negotiated Process**

The developing theoretical literature on interorganizational collaboration underpinning this study emphasizes its emergent, negotiated nature (Gray, 1989; Thomson et al., 2007) and this has been seen in practice as well (Rattelade & Sylvestre, 2012). The results from my study corroborate this conceptualization of collaboration and provide other key insights for the context of a school-university-industry partnership. This emergent, negotiated nature could be inferred implicitly from findings that show the roles and responsibilities changed over time, and explicitly through particular individual statements about overall process. These results suggest that reflecting on process may impact collaborative actions and ultimately success. Beyond this, although there is no shortage of literature characterizing partnership by category along an implied hierarchy or continuum building to more and more organizational interactions, evidence from this study suggests that the notion that collaborations can be evaluated as they progress uniformly along these spectrums obscures the dynamic aspects of collaboration. Additionally, the findings around the dynamics of communication and negotiations at the organizational and individual level provided insight into characterizing collaborative communication within this project and beyond.

**Reflection in Collaborative Practice and Barriers to Change**

The findings support the literature claims of interorganizational collaboration as an emergent, negotiated process and collaborative practitioners might be prompted to reflect on these processes as a means to overcome barriers to change.

The theoretical work in interorganizational collaboration (e.g., Gray, 1989) is based partly in negotiated order theory which emphasizes the interactions between the actors in a dynamic organization system (Day & Day, 1977). Participants not only provided evidence that they experienced an emergent and negotiated process the first year, but several were able to articulate that they were consciously aware of this essential aspect of interorganizational systems, both corroborating the literature and suggesting the importance of reflection in
collaborative practice. For example, there was evidence of the emergent and negotiated nature of interorganizational collaboration in participant statements about collaborative processes of administration such as the process of clarifying responsibilities (e.g., industry partners and teachers seeing their position as assistive to the university role) and in statements positioned at a meta-level about the collaboration itself (e.g., “degree of chaos”).

The individuals that demonstrated an intuitive awareness of the nature of collaboration were potentially better positioned to weather the “conflict and change” inherent in an organization system (Day & Day, 1977, p. 132). If identifying the emergent and negotiated nature of collaboration can be associated with overcoming barriers to organization change in this way, developing a meta-level awareness of collaboration as a process can help accomplish collaborative goals. This is especially important given the characterization of collaborative problems as those organizational issues that are the most complex (Gray, 1989). Management literature supports this point by identifying mitigating barriers to change as a factor in promoting successful partnership (Boddy, Cahill, Charles, Fraser-Kraus, & Macbeth, 1998). Interestingly, though many participants identified processes that suggested this awareness, those most explicit were school administrators and corporate leadership. Being able to temper change with ongoing activities through skillful leadership is important to building strong interorganizational relationships (Casey, 2007). In the education space, administrator views factored into making changes to teaching practice (Berebitsky et al., 2014).

It is clear that the collaboration in year one of the program can be characterized as an emergent, negotiated process by considering participant statements; it is also clear that some individuals were able to identify this process in their own words and connect it to a positivity about, or at the very least an acceptance of, the tumultuous feeling of the initial stages of a partnership. I argued that what follows is the notion that collaborative practitioners might reflect on these processes as a means to overcome barriers to change. Such reflecting allows the practitioner to use their previous experience and knowledge while challenging these preconceived notions as they engage in a novel experience (Schon, 2008). When addressing a messy social issue (Schon, 2008) or ill-defined collaborative problem (Gray, 1989) this becomes particularly salient.
Characterizing Collaboration on a Spectrum

Characterizing collaboration on a spectrum can be a useful tool to talk about differences but should not necessarily be used as a benchmark of progress due to the dynamic nature of collaboration and differing stakeholder perceptions at any given point in the process.

The evidence of collaboration as an emergent process aligns well with the literature characterizing partnership on a spectrum or in categories from across contexts (Fishbaugh, 1997; Kernaghan, 1993; Seitanidi & Ryan, 2007; Thomas et al., 2010). For instance, Thomas et al. (2010) depicts this as a continuum of partnership from individual contacts to organizational relationships and Kernaghan (1993) characterizes partnerships on a spectrum of categories including phony and operational. The findings from my study suggest that, given collaboration as an emergent and dynamic process, these spectrums do not necessarily represent a neat progression towards a fully sustainable partnership but instead that an interorganizational collaboration may travel across and between these scales as it develops.

Furthermore, at any given time, individuals in a collaboration have characterized the partnership differently. For instance, some industry participants discussed the project as charity, aligning with the philanthropy category from Seitanidi and Ryan (2007). Because of this, it would be unwise to say, for instance, the collaboration became consultative (Kernaghan, 1993) simply because some participants clarified their role as subordinate to the university over the year. The bigger picture implies that although their description may fit this category, there is simultaneous evidence fitting other categories and relationship building through structural shifts. Collaborations can become more organized over time (Gray, 1989) while at the same time collaborations can have transitory aspects and fragile structures that change. Characterizing collaboration on a spectrum can provide useful language for partners to talk about differences through the meta-reflection described above but should not necessarily be used as a benchmark of progress. As another example, organizations may use the language around contributory partnership, in which one organization provides sponsorship and suggestions and another holds decision-making power (Kernaghan, 1993), to clarify expectations. The outcome of the conversation may be a shift towards a different model or reaffirmation that their current interactions are working well for everyone.
Managing Communication, Information Sharing, and the Emergence of Key Individuals

Formal and informal communication processes represent an important leverage point for change in school-university-industry partnership. Key individuals serving as brokers of partnership between organizations are important for collaborative success. These individuals must emerge across roles in an organization, though there are trade-offs to mediating collaboration in this way.

Collaboration is a negotiated process rooted in the interactions between individual actors within the interorganizational system under development (Gray, 1989; Thomson et al., 2007). Structures and processes of communication are therefore salient for discussion, specifically articulating factors of success and barriers in light of developments that took place in the first year of this partnership.

The findings showed that cases in which key coordinating individuals emerged as prominent in facilitating collaborative processes, better communication and other relational structures were able to be established. Literature on collaboration also emphasizes these links between individual interactions building to organizational relationships (Thomas et al., 2010) and the idea of a “partnership coordinator” as a broker between partnering organizations (Casey, 2007, p. 80). It follows that to promote success, key individuals should be identified as soon as possible. However, because collaboration is an emergent process, identifying these individuals may not be possible until organizations start to engage in the act of collaborating. This is further evidenced by the fact that in several instances people identified themselves as having an overseer or critical role in funneling communication, but in follow ups, other individuals were identified as key facilitators of communication or these overseers recanted on their description of role. In fostering communication, some individuals were actually fulfilling their job role within their organization (e.g., the New County STEM Specialist, the Deltax liaison, and the University facilitators). This form of partnership coordinator is documented in the literature as researchers serving the key function in collaborating with secondary schools shifted their model to teacher-originated ideas to increase teacher ownership and improve interactions (Dolan & Tanner, 2005). In other school-university-industry partnerships, the university has been conceptualized as a bridge between schools and industry (Craig & Jensen, 2010; Pawloski et al., 2011). However, the findings from this study suggest that coordinators must emerge across organizations and this
critical role must not just fall to the project instigators such as university researchers. Other key individuals, such as particularly involved industry participants at Cornerstone or specific teachers, emerged as leaders in communication through their own passion and involvement. Although efforts were made in the VT PEERS project to establish the means and quality of communication, emergent individual connections were critical to success.

By looking at the collaboration as a system with interconnections driven by communication, we can identify leverage points for improvement. Taking a systemic look at a collaboration as a collection of interactions allows us to consider unique implications for making change. Interconnections in organizational systems have been characterized as working through information sharing (Meadows & Wright, 2008). Much like the notion that in order to find key coordinating individuals to promote collaborative success one has to begin collaborating, the notion of leverage points for improvements is not intuitive (Meadows & Wright, 2008). “Missing information flows is one of the most common causes of system malfunction” and repairing these flows can be impactful (Meadows & Wright, 2008, p. 157). Notably, one participant had critical feedback about teacher interactions but had no channel in which to share that information. One explanation for difficulties might be the nature of distance collaboration, where collaborators operate independently and far apart for much of the time, that raises the “problem of mutual knowledge” (Cramton, 2001). When partners are at a distance, they may attribute collaborator actions to disposition over situation (Cramton, 2001). For example, the industry participant may have changed their perception of why the teacher left the room from negligence to a more realistic interpretation if they were able to see the teacher’s day-to-day. Likewise, teachers may have been able to more acutely feel an industry participant’s discomfort at attempting classroom management. Restoring these connections could mean improvement of the collaboration.

Researcher intervention in the form of qualitative interviews could do double duty as a formal mechanism for sharing feedback between organizations but only if planned as such. In addition to formal channels, efforts should be made towards establishing interpersonal connections (Mattessich et al., 2001).

As a final thought on managing communication in a dynamic system, within the organizations in the VT PEERS project, respecting organizational hierarchy while ensuring buy-in and active communication across this hierarchy was challenging. For instance, within the school systems, a grass roots effort based on teacher involvement may have built more capacity
for collaborative governance, but university instigated administrator meetings were important to ensure buy-in for seeking to make change to teaching practice in schools (Berebitsky et al., 2014), particularly around engineering (Douglas et al., 2016). The partial breakdown in communication within the organizations that participants identified in this project (e.g., teachers being told to participate or misunderstandings around expectations) suggests that trade-offs occur between practicality and promoting investment through communication across levels.

**Autonomy and Investment**

Organizational autonomy is the pull between an individual organization’s and the collective interest in an interorganizational partnership (Thomson et al., 2007). In practice, this most often manifests as tensions between carrying out the day-to-day tasks of the organization and fulfilling obligations to constituents while maintaining their commitment to the collaborative efforts. The findings from my study suggested that, particularly for industry, organizational culture and individuals’ perceptions about the ability to bear the costs impacted investment in collaboration. Even with individual commitment and enthusiasm, external factors such as the constraints of the school system or the teaching profession may also add complexity. Figure 5 illustrates how these factors add elasticity into the system of organizational and collaborative commitments discussed below. Here, the analogy of a spring embedded in a cable is used to demonstrate this dynamic tension with factors that can mitigate or amplify the perception of pull.

**Figure 5. Elasticity in organizational autonomy.**
Corporate Culture and Capacity in Public-Private Partnership

Missing from the theory on collaboration is the potential for the influence of organizational culture on perceptions of organizational autonomy, particularly for businesses in public-private partnership.

In public-private partnerships such as this program, social goals may conflict with economic interests of the company (Stadtler, 2011). The VT PEERS program follows the literature suggestion that it is important to have supervisor buy-in and support to balance this tension in collaborating between businesses and K-12 school systems (Rogers & Cejka, 2006). However, the findings from this study demonstrate that for businesses, leadership buy-in is not enough and the same potential autonomy issues manifested differently depending on the work environment. For example, making up lost work time from participating in the collaboration was discussed differently at different organizations. Because of the capacity that Deltax built for volunteering and because of the company philosophy of Cornerstone to be flexible in their work hours, autonomy was less of an issue than at EchoCorp which had not had a lot of experience participating in similar programs and identified autonomy issues relating to paying employees for nonworking time invested in the partnership.

Notably, a missing component of the theoretical work on interorganizational collaboration is the impact of differences in organizational culture. Hofstede, Hofstede, & Minkov (2010) discuss organizational culture as the well-established and socially constructed norms of behavior within an organization that make it different from other organizations. Although it could be argued that this is a useful concept for discussing multiple aspects of collaboration between organizations, the findings from my study suggest that it is particularly appropriate for a discussion of organizational autonomy. For instance, I found that Cornerstone had a more flexible work environment and a participating employee called their business “a loose type company.” A distinction between loose and tight management control systems is well established in the literature (Hofstede, Neuijen, Ohayv, & Sanders, 1990). As the terms suggest, organizations with tighter control exercise more oversight over operations. For a small company such as EchoCorp, when something goes wrong, the management may call for employees to drop everything and attend to it. Anecdotally, in year two of the project, a scenario much like this unfolded as a major piece of equipment went offline and it was difficult to make contact with
management. A larger company such as Cornerstone has more capacity to handle the unexpected, so it follows that they might fit under a looser model. Being that their position was management and the language of “corporate culture” has taken hold among managers (Hofstede et al., 2010), it is possible that the participant that described Cornerstone as “loose” was using language directly derived from the study of organizational cultures when discussing organizational autonomy. Organizational culture is useful to explain some of these differences under the autonomy dimension from Thomson et al. (2007) as I have done here and could be integrated as the theory underlying collaboration continues to develop.

Balancing Costs with Benefits in Schools

How school leadership balances perceived benefits with costs in a school-university-industry partnership may shed light on our understanding of potential autonomy issues identified in collaborating beyond the charity or outreach model that presumes school benefits without major cost.

Researchers have explored how these collaborations can be made beneficial for businesses (Googins & Rochlin, 2000; Stadtler, 2011), but in limited literature on these sorts of interactions, although school capacity is alluded to, it is not central to the study (Rogers & Cejka, 2006). There appears to be a tacit understanding that anything given to a school will be good for it regardless of the cost. There is evidence of this in nearly every participant interview. For instance, school administrators were keen to take on a new initiative without explicit teacher buy-in. Incentivizing buy-in through intentional inclusion in key activities has been part of similar efforts for educational change (Dolan & Tanner, 2005; LeMahieu, Nordstrum, & Potvin, 2017). Likewise, industry participants frequently cited the benefit to the school system but did not frequently identify school system autonomy concerns. The findings from this study allow me to bring school autonomy considerations to the forefront to shift our understanding of school-university-industry partnerships to include a more critical assessment of school involvement beyond the charity or outreach model that presumes benefits without cost.

For school systems, administrator decisions to collaborate across organizations might be based on perceived benefit but without considering, and therefore without setting up a structure for, the perceived costs. The findings from my study suggest that even though programmatic goals to improve learning and career prospects for youth align well with school goals and
students in rural areas often lack access to resources and support related to college applications (Taylor, 2013), the act of instituting a new collaborative program still poses significant autonomy dilemmas for school systems. At a high level, these dilemmas centered mainly around time and energy, an often neglected consideration in collaboration (Huxham, 1996; Thomson & Perry, 2006). Time spent on a collaboration includes time on actual collaborative efforts such as building credibility with one another through implementing the classroom activities, but it also includes time spent managing autonomy concerns such as maintaining regular classroom obligations (Huxham, 1996). This time spent managing autonomy is often underbudgeted for or ignored completely (Huxham, 1996). My findings suggest that this is especially significant when partnering with school systems where all initiatives are assumed to benefit and costs assumed to be absorbed into day-to-day operations as implied by participant responses. As a specific example, school participants noted issues around standardized testing. Time spent on standardized testing is prioritized across the U.S. education system both historically and currently (Fletcher, 2009; U.S. Department of Education, 2017), but this only came up marginally with administrators and was not central to their decision to participate in the program. Although a teacher hypothesized the programming would eventually improve testing outcomes, another identified noise conflicts with benchmark testing in nearby classrooms.

While companies have responsibilities to their customers, shareholders, or other constituents, school systems have even broader accountability to public demand. Beyond noting issues of time and energy, school participants suggested that having outside influence in the school poses a risk to the fulfillment of obligations to school constituents. For example, a Springfield administrator said, “sometimes when we bring in outside things, there's always that risk of are they going to be appropriate” in terms of communication and classroom management. There is risk associated with allowing outside influence in the public school system anytime an issue intervention is outsourced beyond the school system. Lickteig (2004) highlights the potential for ethical dilemmas posed by such partnerships between corporations and public school systems, and others suggest being wary of motives for companies to provide resources in the classroom lest the school system become a new avenue for advertisement for the products or services of private organizations (Bollier, 2002). Admittedly less insidious but similar in approach, participants in this study from more than one organization suggested that the companies were getting positive public relations by changing the negative association with
manufacturing and the products they produce by accessing a younger generation. Much like with the constraints on time or energy, school and county leadership did not take steps to prepare the outsiders for classroom interactions or inquire about such preparation as the literature suggests (Rogers & Cejka, 2006). Only a baseline of safety due diligence around background checks was performed, and there was little discussion about pedagogy or classroom management. It is possible that the school system had trust in the university mediated partnership or it was unconsidered.

Teaching Beliefs and Autonomy Perceptions

Teachers are important implementers of collaborative plans to make change in schools. Conceptualizing a school-university-industry partnership as an effort to build teacher knowledge and confidence may provide new understanding into the origin of perceived autonomy dilemmas for teachers.

Just as considerations of organizational culture can help explain corporate autonomy dilemmas, teaching beliefs may be considered in discussing school autonomy in school-university-industry partnerships. While it is easy to say that educators do not have enough time during the day to contribute to the collaboration in the way they would like, literature and anecdotal contextual evidence would suggest this other possible explanation rooted in program goals to bring engineering into the science classroom. To be clear, teaching engineering self-efficacy, although part of the interview protocol and broader NSF project, was not explicitly part of the analysis for this particular study. Still, looking through this lens while considering the partnership in part as an effort to build not only teachers’ engineering pedagogical content knowledge but their comfort with the material can shift our understanding of these sorts of partnerships. Engineering pedagogical content knowledge (Sun & Strobel, 2014) requires not only knowledge of engineering but also knowledge of how to apply instructional methods and translating that engineering content to the appropriate grade level; the latter is a noted challenge in the teacher-industry partnership literature (Buxner et al., 2014). It may be intimidating for an educator with low teaching engineering self-efficacy (Yoon et al., 2014) to participate in this project. An administrator implied that if a teacher is overwhelmed with resources or material, they may revert back to the status quo. This could be interpreted as a time-cost issue but also an efficacy issue. What follows is to provide teachers with professional development in engineering
content before they have to interact with engineers in the classroom, though this also has associated time costs.

In the literature on science content knowledge, researchers found a positive link between teaching science self-efficacy and content knowledge (Menon & Sadler, 2016), but the same cannot be said about the engineering education literature (Sun & Strobel, 2014). There is something about engineering in particular, that seems to have decreased the perceived capacity to contribute to the collaboration for teachers and some did explicitly state they were afraid of looking unintelligent in front of their engineering partners or students. Anecdotally in year two of the project, many 6th grade teachers were still happy to hand off control of the class to graduate student volunteers. This typically occurred at the moment a teacher appeared to become uncertain with the material. The literature would suggest that a potential solution to feelings of an autonomy pull rooted in self-efficacy issues would be to provide teachers with an opportunity to take more ownership over the partnership. Although they were not studying self-efficacy or autonomy explicitly, one program’s solution to increasing teacher involvement was to situate teachers as originators of ideas (Dolan & Tanner, 2005). Sharing power in this way is discussed further in the next section and an aspect of much of the literature on partnership (Casey, 2007; Kernaghan, 1993). Mainly due to the time constraints of starting the school year shortly after project funding came through, this was not possible for the VT PEERS program in year one. In year two, this method was used as teachers co-created curriculum outlines with researchers and industry participants at the summer conference event.

**Equity and Exchange**

The theoretical framework used in analysis from Thomson et al. (2007) characterizes mutuality in collaboration as either a process of negotiating a balance of benefits based in competing interests, or from a place of shared goals. The authors make some connections between shared interests and norms of trust and reciprocity, which can be thought of as building credibility over time. However, the findings from my study suggest that the notion of credibility can become even more important when partners approach an exchange of benefits and resources from a position of differing interests as participants in my study have described. Furthermore, Gray (1989) defines public-private partnerships as bridging public and private resources to solve a community-level problem. When speaking about mutuality in a public private partnership, it
may not make sense to discuss an equally beneficial exchange of resources if most of the short-term benefits go to the partner with the closest ties to the community-level issue, in this case the school systems. Equality in exchange may not be possible or desirable, but equity or fair share is. This equity is unlikely when credibility and communication break down and one party perceives an unfair advantage. In interorganizational relationships, “a cousin of power and influence is trust” (Thorelli, 1986). I will discuss the link between credibility and benefits as well as the related power dynamics in public-private partnership in light of these findings and the literature on collaboration.

**Credibility and Benefits in Exchange**

_The theory sparingly connects trust and reciprocal exchange to benefits in partnerships coming from a position of shared mission, but my findings suggest that this credibility building is also extremely salient when the exchanges are positioned from a point of different interests._

Literature on public-private partnership would suggest that the notion of shared benefits are at the heart of successful collaboration (Oberg De La Garza & Moreno Kuri, 2014; Radinsky et al., 2001). However, the best intentions lose meaning without a balance of shared contributions in partnering (Oberg De La Garza & Moreno Kuri, 2014; Thomson et al., 2007). The challenge of ensuring a balance of benefits and contributions is compounded many times in a public-private partnership in which organizations have widely different goals (Stephenson, 1991). In the first year the VT PEERS program, there was strong evidence to suggest an unequal exchange of resources. Moreover, in one case in particular, industry participants felt that teachers were exploiting the aid from the university and industry. While the literature would suggest that this contributed to a breakdown in credibility among partners (Thomson et al., 2007), it can be argued that the situation is more nuanced when the contextual information from the case study is brought into consideration. Recall that the programmatic goals of the project centered around improving the prospects for rural students in these school divisions. It follows that the school system may receive most of the benefits and resources from the collaborative efforts. In truth, this was by design, and teachers and researchers seeking to improve the education system received most of the financial benefits. Benefits to industry were mostly ancillary or long-term according to participants and leadership was aware of this from the start. The literature suggests that for mutually beneficial partnerships involving industry, partners should shift benefits for
corporations towards the primary outputs of the program (Radinsky et al., 2001). However, the messaging in the VT PEERS program to industry was that this was to benefit school systems primarily. There is evidence that industry was accepting of the situation based on the terminology used that is associated with charitable or philanthropic efforts. When partnering cross-sector for change in school systems as the primary goal, the benchmark for collaborative success could be equity over equality in exchange. Equality can be defined as all things being the same for all people. Since we know that people operate at different levels of status and power in a society, a better measure of success for collaborating would be equity or fair share. In partnership, we can conceptualize ensuring equity as a process of evaluating the relative contributions of resources compared to benefits in light of the purpose of the collaboration to determine what balance of costs and benefits is appropriate for each organization. Figure 6 graphically depicts how an uneven exchange of resources can be moderated in this way. The uneven thickness of the arrows represents a difference in the costs and benefits flowing between organizations. Moreover, collaborations involving the public sector such as K-12 public education are oriented towards these goals of improving the prospects of the public sector and therefore an equal share of benefits would not make sense.

Figure 6. Equity in exchange in interorganizational collaboration towards the purpose of addressing a social issue.
Stakeholder acceptance of the equity principle is only possible when efforts are being made to address negative perceptions that impact credibility among partners. This is directly related to the communication structures discussed in the earlier discussion point. An industry participant in case 2 said they had no way to address concerns “without hurting somebody's feelings.” Without means for sharing their negative perceptions of teacher involvement, resentment may grow among partners as in case 2. Beyond offering channels for communicating critique, facilitators of partnership could build collaborator understanding of their benefits and expenditures, even if they are uneven. Interdependence from Gray (1989) is closely tied to the concept of mutuality used in Thomson et al. (2007). Gray (1989) notes that “heightening parties' awareness of their interdependence often kindles renewed willingness to search for trade-offs that could produce a mutually beneficial solution” (p. 11).

**Credibility and Power in Exchange**

*Building this trust or credibility is closely related to power in the partnership literature. People operate at different levels of status and power, especially in partnerships involving school systems. A better measure of success for collaborating would be equity or fair share.*

In discussing perceptions of shared benefits and the credibility connection, we cannot ignore the obvious power differences in public-private partnering that may impact stakeholder actions. Gray and Purdy (2018) explain that “multistakeholder partnerships are governed by power dynamics that affect and are affected by the structure, processes, and relationships of the partnership” (p. 117). Thomson et al. (2007) also suggest that an exploration of power relationship structures in partnering would be valuable to the study of collaboration, though this was notably absent as a central part of their framework. We know from both literature and evidence in this study that teachers may feel intimidated by bringing engineering or industry context into their teaching (Buxner et al., 2014; Sun & Strobel, 2014). An administrator commented that teachers may revert to the status quo of educational practices when presented with an overwhelming prospect. In this way, power disparity in a system is both imposed upon and maintained by those with a low amount of it (Gray & Purdy, 2018). This project sought to scaffold integration into teacher classroom practice to potentially mitigate this, and there is evidence that this was successful in practice from teacher comments on moving forward. However, scaffolding in this way was challenging and had to be more than just bringing
traditionally marginalized stakeholders to the table in systemic problem solving (Midgley, 2006). Providing them explicit opportunity to have a voice and sense of ownership as reiterated throughout this chapter is important. The rhetoric of the VT PEERS program puts the teacher in control; this is why educator is listed before engineering in the acronym.

It is important to note that not all literature on partnership perceives power differences as a barrier to overcome. A managerial perspective would suggest that using power differences between parties is a positive means to effectively manage interorganizational relationships (Belaya & Henrich Hanf, 2009). This falls somewhat in opposition to the research on cross-sector relationships and shared power. It potentially sheds some light on how corporations might view power differences. When industry aligns themselves with a philanthropic approach towards engaging with school partners, as in much of this program, there is a risk of developing paternalistic relationships as opposed to sustainable, mutually beneficial interactions. Program moderators, in this case the university, could encourage the use of neutral or partnering language as a first step in this goal.

**Summary of Contributions**

Through my exploration of a public-private interorganizational collaboration, I have made several distinct contributions at the intersection of education and organizational behavior literature. Despite stretching back several decades, the theoretical work in organizational collaboration is still sparse and developing, perhaps because the terminology around collaboration and partnership is taken for granted in modern vernacular. By systematically applying a framework of collaboration and capitalizing on the rich situational findings possible through a qualitative approach, I have contributed to the development of collaboration theory. In particular, qualitative case study research allowed for the exploration of the collaborative processes involved when organizations with very different contexts and cultures came together. Furthermore, through the research process, I operationalized the five constructs from Thomson et al. (2007) for this context (i.e., collaboration among university, K-12 public education systems, and industry). This is significant given that that much of the literature on collaboration is based in public administration, management, organizational behavior, and related disciplines. By applying this framework to structure my primarily deductive qualitative analysis, I have been able to expand on our understanding of these constructs and the connections between them. For instance, in discussing mutuality, it is important to temper considerations of shared benefits with
the purpose of the collaboration. I proposed the use of the word equity to mean fair share of benefits in a partnership whose goals are clearly aligned to benefit one organization more than others. Connecting to norms of trust, the equity principle appears only to be possible when efforts are made to address credibility issues among partners such as through intentional development of communication structures. Thomson et al. (2007) state that this is mainly a consideration if shared interests are to be the driving force of a collaboration. However, it was clear through this study that even when interests in the collaboration differ, norms of trust and reciprocity impact mutuality. These contributions are summarized in Table 8.
Table 8. Summary of contributions.

<table>
<thead>
<tr>
<th><strong>An Emergent and Negotiated Process</strong></th>
<th><strong>An Emergent and Negotiated Process</strong></th>
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<tr>
<td>Reflection in Collaborative Practice and Barriers to Change</td>
<td>The findings support the literature claims of interorganizational collaboration as an emergent, negotiated process and collaborative practitioners might be prompted to reflect on these processes as a means to overcome barriers to change.</td>
</tr>
<tr>
<td>Characterizing Collaboration on a Spectrum</td>
<td>Characterizing collaboration on a spectrum can be a useful tool to talk about differences but should not necessarily be used as a benchmark of progress due to the dynamic nature of collaboration and differing stakeholder perceptions at any given point in the process.</td>
</tr>
<tr>
<td>Managing Communication, Information Sharing, and the Emergence of Key Individuals</td>
<td>Formal and informal communication processes represent an important leverage point for change in school-university-industry partnership. Key individuals serving as brokers of partnership between organizations are important for collaborative success. These individuals must emerge across roles in an organization, though there are trade-offs to mediating collaboration in this way.</td>
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<th><strong>Autonomy and Investment</strong></th>
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<tr>
<td>Corporate Culture and Capacity in Public-Private Partnership</td>
<td>Missing from the theory on collaboration is the potential for the influence of organizational culture on perceptions of organizational autonomy, particularly for businesses in public-private partnership.</td>
</tr>
<tr>
<td>Balancing Costs with Benefits in Schools</td>
<td>How school leadership balances perceived benefits with costs in a school-university-industry partnership may shed light on our understanding of potential autonomy issues identified in collaborating beyond the charity or outreach model that presumes school benefits without major cost.</td>
</tr>
<tr>
<td>Teaching Beliefs and Autonomy Perceptions</td>
<td>Teachers are important implementers of collaborative plans to make change in schools. Conceptualizing a school-university-industry partnership as an effort to build teacher knowledge and confidence may provide new understanding into the origin of perceived autonomy dilemmas for teachers.</td>
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Implications and Future Work

Multi-Disciplinary Research

Although focused on collaborative processes, by necessity this research has drawn on literature from teacher professional development, broadening participation and STEM education, as well as organizational behavior. As such, the findings have implications for multiple areas of research.

**Stakeholder identification.** To start, in studying collaboration, identifying stakeholders is clearly important. What is less clear is how to establish which stakeholders to spotlight in study. In this study, several scoping decisions were made with regards to who was and who was not included. For example, while parents are an important voice in partnership for school change (Epstein, 2011), they were not part of the central decision making beyond permitting their child to participate, and so were not interviewed. Still, parents would fit the definition of stakeholders as defined by Gray & Purdy (2018) in the issue of STEM workforce development. Future work may include interviews or surveys with parents, who not only represent stakeholders, but also shared constituents among the school system and industry. Talking with parents may extend insights into how this connection may be leveraged to support shared benefits. Additionally, a different approach could be used to identify key brokers of the partnership as they emerge through collaboration, such as analysis of collaborative survey questions, instead of the full coverage approach to interviewing undertaken in this study.

**Distance and the rural setting.** This research can also be seen as an extension of the work engaging with rural youth in authentic engineering activities (Gillen, Carrico, Grohs, & Matusovich, 2018). Participant comments about distance between organizations playing a role in relationship building has particular implications for this rural setting. Researchers might explore how to narrow this physical gap so that it does not become a gap in understanding among partners around expectations (Cramton, 2001). Online mentoring is one way that classrooms have gained access to STEM mentors without being in physical proximity to them (Scogin & Stuessy, 2015). There are potentially useful models to emulate from online teacher support or professional development communities, but maintaining human interaction is key for these sorts of online endeavors. In an investigation of a statewide online professional development program, researchers found that the program still lacked support for interactions (Collins & Liang, 2015).
Whether the focus of study or not, distance between collaborating partners is a clearly important consideration.

**Teaching engineering self-efficacy.** As another implication, it is reasonable to assume that teaching engineering self-efficacy may play an important role in collaborating to bring engineering into middle schools based on the literature and exploration of the organizational autonomy dimension. Through interpretation of the findings, it was reasoned that the tension between school and collaborative commitments for teachers may be due not just to routinized or required teaching tasks already taking up most of the school day, but may also be comfort level with the material. The interview protocol contained questions aimed at investigating teaching engineering self-efficacy. Although these findings were not analyzed through that lens for this investigation, future work might consider merging the collaborative and self-efficacy findings to gain insight into the organizational autonomy dimension.

**The language of partnership.** Beyond voicing autonomy concerns, participants frequently used phrasing that implied relational structures explored through this collaboration. Most often, participants situated themselves as the outsider in the partnership and the other two organizations as collaborators. For example, an industry participant talked about the university and school systems as partnered together and themselves independently. Similarly, teachers saw the university and industry as partnered together to come into their classrooms. Participants also imparted their perceptions of the relative importance of partner roles through word choice such as “assistive” or “supportive” versus “leading” or “facilitating.” A meta-analysis of studies exploring collaboration focusing on the specific language used or a quantizing of the qualitative data from this analysis could yield findings about how the language used relates to actions taken in partnership.

**Reflecting on the research process.** Lastly, the research process itself yielded implications for further study. Every industry participant, teacher, administrator, and university affiliate that was willing participated in the research. Through analysis, it became clear that similar sentiments began to emerge among groups within organizations. It was important to analyze every interview transcript to build a baseline for the critical first year of partnership. However, analysis may be streamlined in the future if coding of interviews stops once saturation is reached (Bowen, 2008). It also became clear through analysis that interview protocol questions designed to collect information around one construct often yielded findings aligning with another
or multiple constructs from Thomson et al. (2007). Upon reflection at the end of the analysis process, these questions are still well suited to yielding results about the collaborative processes underlying the partnership. Still, future work with this interview protocol should appreciate this possibility and consider the extensions to existing theory presented in this discussion.

**Collaboration in Practice**

In considering implications for collaborative practice, I focused on potential supports and barriers implied by the findings and literature for establishing factors of success in the initial stages of a program like VT PEERS. These are broken into two main considerations: setting a strong foundation for partnership and developing a scaffolded approach through program implementation consistent with what we know about the emergent aspects of collaboration.

**Setting a strong foundation for partnership.** Sharing the burden and sharing the benefits is arguably a central piece to collaborative success. To this end, I have developed several questions schools can ask industry and vice versa. For industry, literature suggests collaborating with an eye towards aligning business and social goals (Stadtler, 2011). The findings suggest that many industry participants in this program saw their involvement in the collaboration as charity and that for both schools and industry, perceived capacity to participate was an issue. Asking reflective questions such as these may promote shared benefits while mitigating unexpected expenditure of resources.

Questions for schools to ask industry at the leadership level:

- What are your expectations for committing people and resources?
- Have you partnered with school systems in the past? If so, how would you characterize that experience? What do you hope to get out of this collaboration?
- With the understanding that some reasons for partnering might involve philanthropic aims, what areas for improvement do you see in current or prospective employee skills or knowledge (alignment of business and social goals)?

For collaborating with public school systems, it is clear that alignment with current practices is important both to promote shared benefits and mitigate autonomy concerns. Standardized testing has been an emphasis in schools for many years (Fletcher, 2009) and so alignment with state standards of learning is critical. Beyond this, school personnel raised
concerns about not being able to control the messaging that external collaborators might impart to students. Asking reflective questions before a project that begin to consider alignment with current practices and content or any other concerns about having outsiders in the classroom is important. For example, one participant was worried about the school system reputation if outsiders come in to volunteer and deem the curriculum deficient.

Questions for industry to ask schools:

- Tell us about the content you teach.
- What are your concerns about having our employees in the classroom?
- What are your expectations for classroom involvement and communication outside of class?

Reflective questions that collaborative practitioners can ask themselves or each other is a good first step towards promoting success and could be woven into program governance structures. The findings, particularly around organizational autonomy, would also suggest that budgeting not only for money but also for time would be important. Particularly for industry, budgeting for time in terms of dollar value from the start may help them be clearer about what level of resources they can commit and reduce any capacity issues or misunderstanding during the program. That being said, the findings would suggest that individual employee satisfaction or personal connections between individuals at the organizations may be enough to garner industry support for a program despite what the literature suggests about business benefits (Googins & Rochlin, 2000). A lesser or supportive role, although the language implies negative subordination, may not be a bad thing if industry involvement is based on employee satisfaction or connections.

A scaffolded approach to university-mediated cross-sector collaboration. Many participants saw this project as an excellent professional development experience for teachers. If a collaboration to implement novel classroom activities is also framed as a teacher learning experience, it follows that best practices in teacher professional development should be central. One literature-aligned practice that this project does well is engage with teachers over time beyond one-off trainings and through implementation of new teaching (Gulumhussein, 2013; Wilson, Schweingruber, & Nielsen, 2016). The results of my study indicate that when it comes to engineering, teachers may need additional support which can be scaffolded through
collaboration. Teachers in this project stated feeling overwhelmed with time or having too much of a good thing as an administrator suggested, but in practice facilitators of partnership may need to take action to support teachers in expanding their content knowledge.

Informally, the VT PEERS project has scaffolded university support in the classroom. A step further might be explicit conversations about teaching expectations at each stage and providing opportunities for industry participants and teachers to interact outside of the classroom lesson. Wouldbe facilitators of collaboration might also consider asking administrators to invite teachers to be at the discussion table from the start of the program. Reflecting on collaborative practice and developing a meta-level awareness of the processes underlying it might improve interactions as suggested at the start of this discussion from the standpoint of the reflective practitioner (Schon, 2008). Collaborators might revisit their answers to the reflective questions asked in setting the foundation for partnership.

I developed a reflection tool guided by the major takeaways from my study which can be found in Appendix C. The tool includes seven statements rooted in the discussion points from this chapter and provides associated reflection questions. In this way, it can provide a cheat sheet for what to expect in an interorganizational collaboration and a tool to reflect on and improve collaborative processes.

**Implications for Projects with Both Research and Programmatic Goals**

In this program, the university served multiple functions including grant funder, mediator, researcher, and classroom facilitator. Although more anecdotal than based in the interviews with university affiliates, reconciling research and programmatic goals was a continual challenge throughout the first year. The methodology of design-based implementation research (DBIR) could prove useful as a guide for future collaborative efforts involving researchers and practitioners. Having team members that focused primarily on program tasks or primarily on research tasks was an efficient organizational structure but perhaps led to some of the misunderstandings among the university team and other partners. Taking time for frequent check-ins about what makes good research data and the reality of programmatic experience was the antidote to this dilemma. Ideally, in a DBIR model, these conversations would unfold organically in a cycle of research and practice (LeMahieu et al., 2017).
Some of the issues around the establishment of mechanisms for monitoring and feedback in the first year may have had to do with a misunderstanding of the difference between programmatic and research participation. Every participant invited to the program could participate but not everyone needed to participate in the research. Although this was stated at initial workshops, it was clear that many participants felt that they were directly giving feedback on programmatic activities through their research interviews. What they maybe did not know was that the timeline for processing the interviews was long and information shared in that context would not make it back into program practice as quickly as informal feedback with partners during classroom activities. Universities seeking to mediate partnerships among school systems and industry should frequently remind participants of the difference between research and programmatic participation or commit to using interviews as timely evaluative feedback in addition to research data. Using research outputs to improve practice is central to DBIR methodologies (LeMahieu et al., 2017; Russell, Jackson, Krumm, & Frank, 2013).

**Conclusion**

“Don’t collaborate unless you are willing to thoughtfully consider and educate yourself about the nature of the process involved.” (Thomson & Perry, 2006, p. 28). Thomson and Perry (2006) hold nothing back when expressing the importance of establishing a strong conceptual understanding of partnership and others have echoed the warning that interorganizational collaboration could default to ideological rhetoric over substance if steps are not taken to think critically about the process involved (Longoria, 2005). I conducted this research in order to better understand how interorganizational relationships focused on secondary STEM develop during the initial states of a program. Through this exploration, I built implications for longer term success and evaluated the viability of collaborative theory through use in a new context. In this way, I advanced the literature primarily around organization theory and collaboration but also in STEM education. What is clear through both this discussion and the literature is that no single theoretical approach is enough to completely conceptualize interorganizational collaboration across contexts. Although a single framework was used for analysis, it took the combination of literature from multiple fields of study to build a lens suited for this particular context. The discussion of findings raised implications for the multiple disciplines this research draws upon, including future work, and practical implications for those seeking to collaborate.
When looking at the first year, it is hard to establish conclusions related to sustainability of a partnership. While this research does establish several clear implications for collaborative practice that the literature claims promote success, complete knowledge of how to develop the VT PEERS program into a sustainable partnership is not feasible. Moreover, although having sustainable relationships mean that efforts towards building bonds between individuals and organizations yield long-term benefits, a collaboration that persists beyond initial funding is not necessarily desirable. Collaborating is not the only way to solve complex social problems and “partnerships are not a panacea” (Gray & Purdy, 2018, p. iv). In setting program goals, limited future interaction among partners or partial adaptation of lesson materials may be perfectly satisfactory outcomes. Deciding what sustainability means in a specific program context is important. Although I have identified factors for success in collaboration, for the VT PEERS program, what sustainability means is still being negotiated.
References


Committee on Strengthening Science Education through a Teacher Learning Continuum, Board on Science Education, Division of Behavioral and Social Sciences and Education, Teacher Advisory Council, & National Academies of Sciences, Engineering, and


Teacher Advisory Council, Division of Behavioral and Social Sciences and Education, National Academy of Engineering, & National Academies of Sciences, Engineering, and


Appendices

Appendix A. Online Survey

The following survey asks you to answer a few questions about your perception of and participation in the VT PEERS program. The survey should take 10-15 minutes.

Reminder: While the survey requests your name, this information is only used internally by the team from Virginia Tech to study how your responses change over the life of the project. Your name will never be used or associated with your survey responses in any communication or publications. This survey is covered by Virginia Tech Institutional Review Board (IRB) 17-117.

1. Please type your Last Name

2. Please type your First Name

3. Please indicate your primary role related to the VT PEERS project:
   
   If Please indicate your primary role related to the VT PEERS project: = School administrator (for example, principal or superintendent)
   Or Please indicate your primary role related to the VT PEERS project: = Teacher

4. Indicate the school system in which you work

   If Please indicate your primary role related to the VT PEERS project: = Industry Partner

5. Indicate the industry partner you represent:

   If Please indicate your primary role related to the VT PEERS project: = School administrator (for example, principal or superintendent)
   Or Please indicate your primary role related to the VT PEERS project: = Teacher
   Or Please indicate your primary role related to the VT PEERS project: = Industry Partner
   Or Please indicate your primary role related to the VT PEERS project: = University Affiliate (for example, graduate assistant or faculty)

6. For the questions that follow, "partner organizations" include the school system(s), middle school(s), industry partner(s), and university (Virginia Tech). The "program" refers to the VT PEERS project. If you cannot evaluate a statement, leave it blank.
   To what extent do you agree with the following statements concerning the VT PEERS project. Scale (1 - “not at all” to 7 - “to a great extent”)
   - My organization can count on our partner organizations to meet their obligations to this program.
   - Partner organization meetings accomplish what is necessary for the program to function well.
   - Partner organizations (including your organization) agree about the goals of the program.
   - Partner organizations (including your organization) have combined and used each other’s resources so all partners benefit from collaborating.
• Partner organizations (including your organization) work through differences to arrive at win–win solutions.
• Partner organizations take your organization’s opinions seriously when decisions are made about the program.
• The program hinders your organization from meeting its own organizational mission.
• The people who represent the partner organizations in the collaboration are trustworthy. (You feel what your organization brings to the collaboration is appreciated and respected by partner organizations.
• You, as a representative of your organization in the collaboration, understand your organization’s roles and responsibilities as a member of the collaboration.
• You, as a representative of your organization, feel pulled between trying to meet both your organization’s and the collaboration’s expectations.
• Your organization achieves its own goals better working with the partner organizations than working alone.
• Your organization brainstorms with partner organizations to develop solutions to mission-related problems facing the collaboration.
• Your organization feels it is worthwhile to stay and work with partner organizations rather than leave the collaboration.
• Your organization shares information with partner organizations that will strengthen their operations and programs.
• Your organization’s independence is affected by having to work with partner organizations on activities related to the collaboration.
• Your organization’s tasks in the collaboration are well coordinated with those of partner organizations.

7. Indicate your confidence each organization will meet its obligations to this program. If you have not interacted with a specific partner, do not rate it. Scale (1 - “not confident at all” to 7 - “extremely confident”)

If Please indicate your primary role related to the VT PEERS project: = Industry Partner
And Please indicate your primary role related to the VT PEERS project: = University Affiliate
(for example, graduate assistant or faculty)

8. Please indicate your level of agreement with the following statements. Scale (1 - “strongly disagree” to 7 - “strongly agree”)
• I am confident in my ability to work effectively with the public school system.
• I am confident in my ability to interact with middle school students.
• I am confident in my ability to teach middle school students about engineering.
• I am confident in my ability to represent my organization in public schools.
• Engineering content is relevant for middle school students.

If Please indicate your primary role related to the VT PEERS project: = Teacher

9. To what degree do you agree with the following statements. Scale (1 - “not at all” to 7 - “to a great extent”)

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• I can explain the different aspects of the engineering design process.
• I can discuss how given criteria affect the outcome of an engineering project.
• I can explain engineering concepts well enough to be effective in teaching engineering.
• I can assess my students’ engineering products.
• I know how to teach engineering concepts effectively.
• I can teach engineering as well as I do most subjects.
• I can craft good questions about engineering for my students.
• I can employ engineering activities in my classroom effectively.
• I can discuss how engineering is connected to my daily life.
• I can spend the time necessary to plan engineering lessons for my class.
• I can explain the ways that engineering is used in the world.
• I can describe the process of engineering design.
• I can select appropriate materials for engineering activities.
• I can create engineering activities at the appropriate level for my students.
• I can stay current in my knowledge of engineering.
• I can recognize and appreciate the engineering concepts in all subject areas.
• I can guide my students’ solution development with the engineering design process.
Appendix B. Interview Protocols

Pre-year semi-structured interview protocol for school system personnel. The following questions were adjusted by the interviewer depending on the participant being interviewed (i.e. teacher, principal, or county administrator).

[Environment] Have you been involved in collaborative curriculum development or delivery in the past? Describe.

[Membership] What was your perception of community partner before this project began? Virginia Tech?

[Membership] What influenced your decision to participate in this project?

[Purpose] In your opinion, what outcomes might result from this collaboration? <Prompt for positives and negatives> <Prompt for students, school, you personally>

[Mutuality] Who do you think is benefiting from this collaboration?

[Autonomy/Governance/Administration] What role will/have you played in the collaboration?

[Autonomy/Governance/Administration] What role will/has Virginia Tech/industry partner played in the collaboration?

[Communication] Have you gotten the information you need to be successful in implementing the curriculum?

[Norms] Why do you think Virginia Tech and your industry partner are part of this program?

[Conception of engineering] There are many ways to define engineering. How would you define engineering? Do you ever describe engineering for your students? If so, how do you describe it? If not, why not?

[Conception of engineering] What do you think of when you think of engineering careers? Do you talk to your students about engineering careers? If so, what kinds of things to you say? If not, why not?

[Conception of engineering] Do you know any engineers? Who are they and how do you know them? What type of engineering work do they do?

[Conception of engineering] What content would you expect in an engineering lesson plan?

[self-efficacy] How prepared do you feel to teach engineering? What factors contribute to your feelings of preparedness? <prompt for if taught or not before if not given>
self-efficacy] What kinds of professional development, if any, have you experienced regarding engineering or teaching engineering? How did those experiences go? What was helpful about them? What was less-than-helpful? <prompt for pre-service if not given>

motivation] Do you think it is important to teach engineering to middle school students? Why or why not?

motivation] Are you motivated to teach engineering to middle school students? Why or why not?

Pre-year semi-structured interview protocol for industry personnel.

Environment] Have you been involved in collaborative work with the school system in the past? Describe.

Membership] What was your perception of this school before this project began? Virginia Tech?

Membership] What influenced your decision to participate in this project?

Purpose] In your opinion, what outcomes might result from this collaboration? <Prompt for positives and negatives> <Prompt for students, school, you personally>

Mutuality] Who do you think is benefiting from this collaboration?

Autonomy/Governance/Administration] What role will/have you and your company played in the collaboration?

Autonomy/Governance/Administration] What role will/has Virginia Tech/the school and teacher played in the collaboration?

Communication] Have you gotten the information you need to be successful in the project?

Norms] Why do you think Virginia Tech and the school are part of this program?

Self-efficacy] How capable do you feel about teaching engineering to middle schoolers? What factors contribute?

Motivation] Do you think it is important to teach engineering to middle schoolers?

Pre-year semi-structured interview protocol for university affiliates.

Environment] Have you been involved in collaborative work with these specific school systems or industry partners in the past? Describe.
[Membership] What was your perception of these schools and industry partners before this project began?

[Membership] What influenced your decision to participate in this project?

[Purpose] In your opinion, what outcomes might result from this collaboration? <Prompt for positives and negatives> <Prompt for students, school, industry, you personally>

[Mutuality] Who do you think is benefiting from this collaboration?

[Autonomy/Governance/Administration] What role will/have you and the university team played in the collaboration?

[Autonomy/Governance/Administration] What roles will/have the industry partners/the schools and teachers played in the collaboration?

[Communication] Have you gotten the information you need to be successful in the project?

[Norms] Why do you think industry partners and the schools are part of this program?

Post-year semi-structured interview protocol for school system personnel.

As with the pre-year interviews, the following questions were adjusted by the interviewer depending on the participant being interviewed (i.e. teacher, principal, or county administrator).

Thank you for participating in VT-PEERS this year. Now that we have completed Year 1 of VT-PEERS, we are interested in your thoughts on your experiences, views, and insights. As possible, if you can provide an example, please do. We are interested in all thoughts, positive, negative, and neutral.

[Purpose] In your opinion, what outcomes might result from this collaboration? <Prompt for positives and negatives> <Prompt for students, school, you personally> <Prompt for change since start of partnership>

[Mutuality] Who do you think is benefiting from this collaboration? Why/How? <Prompt for which students are benefiting> <Prompt for change since start of partnership>

[Autonomy/Governance/Administration] What role will/have you played in the collaboration? <Prompt for change since start of partnership>

[Autonomy/Governance/Administration] What role will/has Virginia Tech/industry partner played in the collaboration? <Prompt for was help for 6th grade classes appropriate for student learning needs? Was the amount of VT engagement as expected?> <Prompt for change since start of partnership>

What do you see as your/other partners "ideal" role? Why is this different from reality?

If the project ended this year, would you be comfortable contacting (insert industry partner) in the future?
[Communication] Have you gotten the information you need to be successful in implementing the curriculum?

[Norms] Why do you think Virginia Tech and your industry partner are part of this program?

[Overall] Any other thoughts about how has the collaboration changed over the first year? How has it changed for you specifically? What, if any, specific challenges that you encountered (or you think the project encountered) during the first year?

[Conceptions of engineering] Have your conceptions of engineering or engineers changed since the start of this partnership? If so, how? What factors contributed?

[Self-efficacy] Have your feelings about your ability to teach engineering changed since the start of this partnership? Why or why not? What factors contributed? <Prompt for both positive and negative changes to self-efficacy>

[motivation] Has your motivation to teach engineering changed since the start of the partnership? Why or why not? What factors (people or things) contributed?

[motivation] What barriers, if any, do you anticipate in teaching your students about engineering in middle school? Are these unique to you or your setting, how? [from literature, common answers are lack of teacher knowledge, lack of training, lack of time, lack of administrative support]

Have any barriers changed since the start of the partnership (either less or more)?

[motivation] What, if anything, do you think makes teaching middle school students, in rural communities, about engineering different than other communities?

[motivation] What, if anything, makes teaching middle school students in your community about engineering different than other communities?

[student engagement] We’ve heard from other teachers that they are surprised at the variety of learners that are engaged during these activities. Have you noticed anything along these lines in your class?

[DAET triangulation] In analyzing the DAET, we noticed students from your class [specific data e.g., saw that students wrote about helping people but does not match drawings here], we were wondering if you could provide any insights into why this may be?

[broadening participation] What do you think are the barriers or supports to pursuing engineering as a career for your students?

[classroom change] Did having VT PEERS in your classroom change any routine dynamics for the day or surrounding days? How? Was/were they helpful/not helpful? <prompt for the
teacher's norm and for the students' norms> (in some situations we noticed the principal entering the classroom and even participating in some cases; how might this change the classroom norms)

[Future Plans] So, you must be thinking ahead to next steps, what would you want next year to look like? <prompt for any steps that have taken towards actualizing their vision>

**Post-year semi-structured interview protocol for industry personnel.**

Thank you for participating in VT-PEERS this year. Now that we have completed Year 1 of VT-PEERS, we are interested in your thoughts on your experiences, views, and insights. As possible, if you can provide an example, please do. We are interested in all thoughts, positive, negative, and neutral.

[Purpose] In your opinion, what outcomes might result from this collaboration? <Prompt for positives and negatives> <Prompt for students, school, you personally> <Prompt for change since start of partnership>

[Mutuality] Who do you think is benefiting from this collaboration? <Prompt for change since start of partnership>

[Autonomy/Governance/Administration] What role will/have you and your company played in the collaboration?

Within your company, how well known do you think this project is? How do other people talk about it? <prompt for peers, executive mgt, others>

[Autonomy/Governance/Administration] What role will/has Virginia Tech/the school and teacher played in the collaboration? <Prompt for change since start of partnership>

What do you see as your/other partners "ideal" role? Why is this different from reality?

If the project ended this year, would you be comfortable working with (insert school partner) in the future?

[Communication] Have you gotten the information you need to be successful in the project?

[Norms] Why do you think Virginia Tech and the school are part of this program?

[Overall] Any other thoughts about how has the collaboration changed over the first year? How has it changed for you specifically?

What, if any, specific challenges that you encountered (or you think the project encountered) during the first year?

[Self-efficacy] Have your beliefs about your capability to teach engineering to middle schoolers changes since the partnership started? Why or why not? What factors contribute? <Prompt for both positive and negative changes to self-efficacy>
[Motivation] Have your beliefs about the importance of teaching engineering to middle schoolers changes since the partnership started? Why or why not? What factors (people or things) contribute?

[broadening participation] What do you think are the barriers or supports to pursuing engineering as a career for the students you have worked with?

[Future Plans] So, you must be thinking ahead to next steps, what would you want next year to look like? <prompt for any steps that have taken towards actualizing their vision> <prompt for barriers such as more resources needed>

Post-year semi-structured interview protocol for university affiliates.

[Purpose] In your opinion, what outcomes might result from this collaboration? <Prompt for positives and negatives> <Prompt for students, school, industry, you personally> <Prompt for change since start of partnership>

[Mutuality] Who do you think is benefiting from this collaboration? Why/How? <Prompt for which students are benefiting> <Prompt for change since start of partnership>

[Autonomy/Governance/Administration] What role will/have you and the university team played in the collaboration? <Prompt for change since start of partnership>

[Autonomy/Governance/Administration] What roles will/have the industry partners/the schools and teachers played in the collaboration? <Prompt for change since start of partnership> What do you see as your/other partners "ideal" role? Why is this different from reality?

[Communication] Have you gotten the information you need to be successful in the project?

[Norms] Why do you think industry partners and the schools are part of this program?

[Overall] Any other thoughts about how has the collaboration changed over the first year? How has it changed for you specifically? What, if any, specific challenges that you encountered (or you think the project encountered) during the first year?

[Broadening participation] What do you think are the barriers or supports to pursuing engineering as a career for your students? <prompt for our students being rural and (except Bedford) Appalachian>
Appendix C. Evidence-Based Reflection Tool

Guidelines: This tool can be used both as personal reflection on the process of collaborating and to spark discussion among partners. Though it may be introduced in the early stages of establishing a partnership, these concepts and reflection questions are meant to be considered continuously throughout an ongoing collaboration.

**Collaboration is not set it and forget it.**

In any project, the best laid plans often bear little resemblance to the ultimate outcome. Unforeseen circumstances require improvised changes to be made. Preparing ourselves for change as an inherent component of collaborating with multiple organizations might help us better weather the ups and downs of partnership.

Reflection Questions
- How comfortable am I with uncertainty?
- How have I been involved with or impacted by changemaking within my own organization?

**Collaborators have different views of success at any given point in time.**

While there is no shortage of metrics by which to compare the progress of relationship building in a collaboration, remember that everyone has their own frame for viewing collaborative success.

Reflection Questions
- What aspects of this collaboration are most important to me?
- What would my peers say is most important?

**A Collaboration is only as good as its people.**

It’s easy to talk about collaboration and organizations in the abstract, but it is a network of interacting people that make up these entities. Building lasting relationships requires investment from individuals willing to span organizations and be mediators of partnership.

Reflection Questions
- What do I see as my role in the collaboration?
- Who around me acts as a bridge between our organizations? At what level do they operate?

**Just because an organization is getting something new doesn’t mean collaborative work is value added by default.**

Collaboration can be a gift tied to significant responsibility. While it might be tempting to assume that because an organization stands to gain significantly from a collaboration that costs to them will be negligible, there can be hidden tensions to participation.

Reflection Questions
- How does collaborating impact my (and my partners’) day-to-day work?
- When is adding a new collaboration too much of a good thing?
Collaboration requires identifying what your unique expertise is bringing to a project.

Even in partnerships that appear to be charity at face value, strong collaborators leverage the strengths of all partners.

Reflection Questions
  • What strengths do I bring to the partnership as an individual? As an organization?
  • What are my partners’ strengths and expertise?

Unequal costs and benefits are okay if collaborators agree on the balance.

Particularly in collaboration towards a social goal or one that stands to benefit the community at large, an unequal balance of costs and benefits among organizations may be the most logical structure. However, all partners must agree on this shared purpose and its implications.

Reflection Questions:
  • Who should benefit the most from the collaboration?
  • What are my expectations for this primary beneficiary in terms of resource contribution?

Balancing costs and benefits gets easier as collaborators build trusting relationships.

Many of the reflective questions in this guide become easier to answer as relationships develop over time and partners begin to feel more comfortable with the promises and expectations around their collaborators’ contributions.

Reflection Questions
  • Who do I trust in the partnership to contribute what they promised and why?
  • How would I or my partners react to additional unanticipated work?