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A multiple case study of an interorganizational collaboration: Exploring the first year of an industry partnership focused on middle school engineering education

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Abstract

Background: Calls to improve learning in science, technology, engineering, and mathematics (STEM), and particularly engineering, present significant challenges for school systems. Partnerships among engineering industry, universities, and school systems to support learning appear promising, but current work is limited in its conclusions because it lacks a strong connection to theoretical work in interorganizational collaboration.

Purpose/Hypothesis: This study aims to reflect more critically on the process of how organizations build relationships to address the following research question: In a public–private partnership to integrate engineering into middle school science curriculum, how do stakeholder characterizations of the collaborative process align with existing frameworks of interorganizational collaboration?

Design/Method: This qualitative, embedded multiple case study considered in-depth pre- and post-year interviews with teachers, administrators, industry, and university personnel during the first year of the Partnering with Educators and Engineers in Rural Schools (PEERS) program. Transcripts were analyzed using a framework of interorganizational collaboration operationalized for our context.

Results: Results provide insights into stakeholder perceptions of collaborative processes in the first year of the PEERS program across dimensions of collaboration. These dimensions mapped to three central discussion points with relevance for school–university–industry partnerships: school collaboration as an emergent and negotiated process, tension in collaborating across organizations, and fair share in collaborating toward a social goal.

Conclusions: Taking a macro-level look at the collaborative processes involved enabled us to develop implications for collaborative stakeholders to be intentional about designing for future success. By systematically applying a framework of collaboration and capitalizing on the rich situational findings possible through a

qualitative approach, we shift our understanding of collaborative processes in school–university–industry partnerships for engineering education and contribute to the development of collaboration theory.

KEYWORDS
cross-sector, industry involvement, middle school, qualitative, STEM

1 | INTRODUCTION

As initiatives to improve K-12 student learning in science, technology, engineering, and mathematics (STEM), and particularly engineering, have grown in recent years, so has the burden on teachers and school systems. Despite some successful efforts, formal mechanisms for change are still varied or deficient (National Academy of Engineering [NAE] and National Research Council [NRC], 2014). While we will need well-prepared educators to address new learning outcomes, teachers are already overworked (Scholastic and the Bill and Melinda Gates Foundation, 2012), and researchers position them as underprepared to meet these challenges (Antink-Meyer & Meyer, 2016; Hammack & Ivey, 2019; Judson et al., 2016). We argue that partnerships among school systems, engineers, and researchers may help alleviate issues of teacher preparedness, while supporting overburdened schools in addressing national STEM workforce development objectives. At face value, these cross-sector connections make sense, and corporate–community partnerships have the potential for shared benefits including business benefits and favorable student outcomes for learning (Googins & Rochlin, 2000; Rogers & Cejka, 2006).

1.1 | The need for the study

Despite a promising outlook, there is still a gap in our understanding about how to establish these partnerships for mutual success. The empirical work on interorganizational collaborations (i.e., collaboration across organizations) 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 et al., 2011; Rogers & Cejka, 2006), or focuses on specific dimensions of collaboration such as mutual benefits (e.g., Radinsky et al., 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.

Our study helps fill the need for empirical work that interprets interorganizational collaborations in the context of K-12 engineering education but through a lens of collaborative theory. We build additional theoretical understanding of how interorganizational relationships to implement engineering education in public middle school science classrooms emerge and change during the initial stages of partnership and offer implications for collaborative practitioners. To this end, we addressed the following research question: In a public–private partnership to integrate engineering into middle school science curriculum, how do stakeholder characterizations of the collaborative process align with existing frameworks of interorganizational collaboration?

1.2 | Study context

1.2.1 | Integrating engineering in K-12 schools

Although sidelined in the past, engineering has increasingly become formalized in K-12 curriculum (Brophy et al., 2008; Carr et al., 2012). The Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) in particular represent a turning point in nation-wide learning standards for engineering. Aligned with the NRC's 2011 Framework for K-12 Science Education, these were developed by states in conjunction with the National Science Teachers Association and the American Association for the Advancement of Science. Our program curriculum aligns with both the NGSS engineering and state standards of science to take an integrated approach. Past efforts to implement NGSS reveal exogenous and endogenous factors impacting success, including lack of support or difficulties connecting with current practice (Biggers et al., 2016; Douglas et al., 2016; Lesseig et al., 2016; Turner, 2015). Middle school teachers in particular, like those at the focus of this study, report feeling less prepared than high school teachers to implement NGSS science

and engineering practices (Haag & Megowan, 2015). Beyond this, integrating STEM subjects means more than just simple combination; it means explicitly considering connections (NAE and NRC, 2014; Sanders, 2013). Partnering these diverse organizations represents an attempt to promote these cross-curricular connections. Building these connections can be thought of as the combination of teaching expertise and content knowledge. The pedagogical content knowledge (Shulman, 1986) that results from leveraging teacher experience and industry knowledge is the understanding of how best to teach the content including, for instance, ways of presenting the topic and an understanding of common misconceptions.

1.2.2 | Program overview

This work takes place within the first year of the Partnering with Educators and Engineers in Rural Schools (PEERS) research and outreach project funded through the National Science Foundation (NSF) Innovative Technology Experiences for Students and Teachers (ITEST) program. The project brings together middle school teachers from three rural school divisions and volunteers from science and engineering corporations to design and implement hands-on, standards-aligned, and locally relevant integrated science and engineering lessons over 3 years. The overarching project is three partnerships in one as each school division and associated industry partner have their own unique context, but the lessons and university personnel are shared across divisions. Researchers and other university personnel mediate these interactions and also implement the lessons in the classroom with the teachers. The project officially started in 2017, and although some of the partners may have interacted on a one-off basis in the past, the partnership was not pre-existing before the ITEST grant began. While the duration of this funded partnership is determined by the timeline of the grant, we are hopeful that the relationships, particularly between industry and school systems, persist. This study is in part motivated by the desire to understand the collaborative processes on a deeper level and provide suggestions for sustainable development. The full programmatic description of this project can be found in the study by Grohs et al. (2020). Table 1 details the specific activities undertaken through the partnership by teachers, university, and industry stakeholders. Most administrators served as the initial point of contact for schools and in recruiting teachers who were strongly encouraged to join the program. Industry partners were identified through personal and professional connections of university faculty and sought to have further impact on workforce development in their community.

1.2.3 | Program implementation

The goals of the program are twofold: (1) increase youth awareness of, interest in, and readiness for diverse engineering-related careers and educational pathways and (2) build capacity for schools to sustainably integrate engineering skills and knowledge of diverse engineering-related careers and educational pathways. To deliver these goals, schools and corporate partners completed approximately one classroom lesson per month and attended a cross-division summer summit at which team building and curricular activities took place. While most of the coordination in preparation for these lessons was funneled through the university, some teachers and corporate partners did communicate outside of these structured opportunities for interaction. The classroom activities aligned with science standards already in use by the teachers' school counties and the NGSS Science and Engineering standards for middle school (NGSS Lead States, 2013). Design of these lessons focused on several elements: aligning with existing learning standards, emphasizing hands-on classroom activities, forging connections to engineering thinking or engineering careers, and creating relevancy for rural youth (Grohs et al., 2020). Evaluating criteria used to design and assess the efficacy of the lesson designs were adapted from Cunningham and Lachapelle (2014). The three school divisions shared nearly all the same lessons in this first year with some variations due to school schedules and snow days. Teachers identified standards and the appropriate time of year they should be addressed according to county pacing guides, which accounts for some variation even though the actual learning standards addressed are the same across cases. Lessons included topics such as the scientific method, osmosis and diffusion, ecosystem interaction, water filtration, and earth and space. These lessons addressed the state science standards while integrating engineering and career-related content (e.g., civil engineering and water treatment in the water filtration lesson).

2 | A FRAMEWORK OF COLLABORATION

While the literature on K-12 engineering education informed our project implementation, to study the collaborative processes that promote ultimate sustainability and success, we needed to utilize the theory of organizational

TABLE 1 Specific activities of collaborating partners both inside and outside the classroom from Table 1 in Grohs et al. (2020)

	Outside class	In class
Teachers	• Identify appropriate standards of learning and problem areas • Provide feedback on written lessons around age/content-appropriateness • Set the stage for PEERS lessons with content from prior classes • Interpret school system culture for outside partners • Share relevance and connect context and lesson plans to dovetail with programmatic engagement	• Co-facilitate activities • Provide classroom management and details around school protocol • Facilitate administrative program needs for lessons (e.g., alternative spaces, support materials)
Industry	• Provide feedback on written lessons around engineering/career connection • Provide materials for interventions that come from company work products • Provide insight to partners to deepen relationship to industry activities and material connections for activities in the classroom	• Co-facilitate activities • Offer examples from their own working experience to students • Highlight processes and activities in their facilities connected to the lesson topics
University	• Direct lesson development within teacher-stated constraints • Coordinate scheduling and overall communication about project happenings • Procure, organize, and distribute lesson materials across schools and classrooms • Coordinate industry and university volunteers for in-class activities • Schedule and coordinate observation and observation protocols for activities • Communicate logistics and content elements of lessons with all partners	• Co-facilitate activities • Scaffold teacher independence in leading the activities and interacting with students around engineering concepts • Invite industry to participate by sharing their experiences • Oversight of university volunteers in the classroom • Trust building with teachers, industry, and administrators

Abbreviation: PEERS, Partnering with Educators and Engineers in Rural Schools.

relationships. This presented a significant challenge as little previous work in engineering education bridges these fields of study in a robust way. Moreover, we quickly found that "no single theoretical perspective provides an adequate foundation for a general theory of collaboration" (Gray & Wood, 1991, p. 3). For this reason, we bring together multiple orientations to provide a baseline for a theoretical understanding of a public–private, interorganizational collaboration in our study context while focusing on a single framework of choice for analysis. The foundational work of Barbara Gray (1989) served as a starting point. Gray (1989) presents work toward "a theory of collaboration as an emergent interorganization process" in contrast to previous work that focuses on transactions among organizations or structural aspects of the relationship (p. 227). She 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.

Representing later, and more operationalized, interpretations of a theory of interorganizational collaboration, several works across disciplinary contexts characterize partnership work on a spectrum of categories or continuum (Fishbaugh, 1997; Kernaghan, 1993; Mattessich et al., 2001; Thomas et al., 2010; Thomson et al., 2007). We chose the most developed of these frameworks to guide our analysis. This framework from Thomson and Perry (2006) and Thomson et al. (2007) is currently being applied across varied contexts (e.g., Roberts et al., 2017) and provided our team with the following dimensions of collaboration: governance, administration, organizational autonomy, mutuality, and norms of trust and reciprocity. As will become apparent in the discussion of findings, these dimensions are not exclusive but are often concurrent, integrated processes. Each dimension is presented below with additional literature support to bring them into the context of a school–university–industry partnership for our study. These are not necessarily principles of best practice that guided our programming but rather were constructs that we explored through our research to build a better understanding of the collaborative processes at play.

2.1 | Governance and administration

Governance refers to the idea that participants in a collaboration cooperatively develop structures and rules related to decision-making and other constraints related to collective action. In the literature, central to partnership is the notion of shared goals and planning (Henderson, 1990; Kernaghan, 1993) for strategic education partnership (Thomas et al., 2010) and toward promoting sustainability (Gardner, 2011). Governance is a negotiated process that takes place over time as a collaboration emerges (Thomson et al., 2007).

The dimension of administration considers the difficulty of transitioning from governance to taking actions toward meeting goals when independently operating parties come together to collaborate. Considerations of communication practices, roles, and responsibilities replace traditional hierarchical administrative systems. Shifting roles in partnerships between universities and schools has manifested as an effort to allow teachers to take more ownership over the curriculum by originating ideas (Dolan & Tanner, 2005).

2.2 | 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). Others have described a similar concept as the pull between collaborative and self-interest on a team (Colbry et al., 2014). When translating advanced material to schools, there can be concerns about the appropriateness of the material and level of complexity (Laursen et al., 2007). Universities may serve as bridges between industry and K-12 schools in collaboration, keeping the flow of mutual understanding among parties (Pawloski et al., 2011). Nonteacher classroom volunteers may receive training in pedagogy to lessen tension with teacher concerns (Rogers & Cejka, 2006).

2.3 | Mutuality

The dimension of mutuality addresses this tension of interests as a necessary component of building "beneficial interdependencies" based either on different or shared interests (Thomson et al., 2007, p. 27). In the business sphere, the notion that shared benefits, explicitly defined, would appear necessary for private sector partnership (Henderson, 1990). In cross-sector partnership, if only the public entity benefits, then the relationship may look more like charity than partnership. If only the business benefits, that might amount to exploitation. 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). Among these extremes is an interorganizational relationship with shared benefits.

The underlying assumption of cross-sector partnership is that each organization contributes resources for which they are uniquely suited to provide (Googins & Rochlin, 2000). Shared benefits based on different interests and an exchange of resources in this way is called complementarity (Powell, 1990). Exchanges of expenditures and benefits can be intangibles such as time or expertise (Hamos et al., 2009) or tangibles such as student design projects being incorporated into corporate design work (Radinsky et al., 2001). For corporations, benefits may also be secondary products of collaboration, such as media attention (Radinsky et al., 2001), establishing a corporate identity with the collaborative issue to attract new employees (Stadtler, 2011), or increasing current employee morale (Googins & Rochlin, 2000).

2.4 | Norms of trust and reciprocity

The last dimension considers that success concerning the dimension of mutuality is unlikely without building credibility among partners. Trust is another dynamic identified in the literature on partnership (Kernaghan, 1993; Oberg De La Garza & Moreno Kuri, 2014), and is conceptualized through Thomson et al. (2007) as the building of credibility. Building this means partners believe that their collaborators will make every effort to meet their obligations and avoid deception or taking advantage (Thomson et al., 2007). Although their framework discusses building trust among

organizations, corporations can be large entities and there can be uncertainty about how time spent away from the office is viewed by management, even in well-established public–private partnerships (Rogers & Cejka, 2006).

3 | RESEARCH DESIGN

Consistent with the approach to utilize frameworks and literature from other fields, we position ourselves as pragmatists, motivated by using any and all means to develop solutions to the research problem (Creswell, 2014; Patton, 2002). We applied qualitative, embedded multiple case study techniques (Yin, 2014) to investigate the evolution of the first year of a multiyear collaboration involving public educational systems (i.e., school divisions and an institution of higher education) and science and engineering companies. Further consistent with the pragmatic perspective, we took a more structured approach to qualitative inquiry as opposed to a mostly inductive design. In case study inquiries, although this approach runs the risk of losing and reducing context, findings are more "economical" and "comparable" (Miles et al., 2013, p. 20). Case studies methodologies that rely on a primarily qualitative approach are prevalent in the literature (e.g., Abma & Stake, 2014; Baxter & Jack, 2008).

Our embedded multiple case study design consisted of three cases—one for each school division and corresponding industry partner bounded by the first year and their geographic location: (1) South County and Cornerstone Industry, (2) Springfield County and EchoCorp, and (3) New County and Deltax Corporation. In accordance with IRB approval, pseudonyms were applied to all organizations and individuals to protect confidentiality. Figure 1 shows the case study design adapted from Yin (2014). 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). In this study, the embedded units of analysis are each stakeholder group: administrators, teachers, industry partners, and university affiliates.

3.1 | Study setting and participants

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). This work takes place within a larger NSF funded research and programmatic project through the ITEST program (DRL—1657263). There are four major stakeholder groups that make up the PEERS collaboration and form the sample for this study: administrators, teachers, industry partners, and university affiliates. Justification for these groups under study is presented in Table 2.

A purposeful case selection and construction in our study promoted theoretical validation (Walther et al., 2013). The schools involved are representative of rural school districts across the country. These communities face 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. It is also clear that these counties are representative for some of the challenges facing rural areas such as poverty and lower educational attainment (Alleman & Holly, 2012). For instance, 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

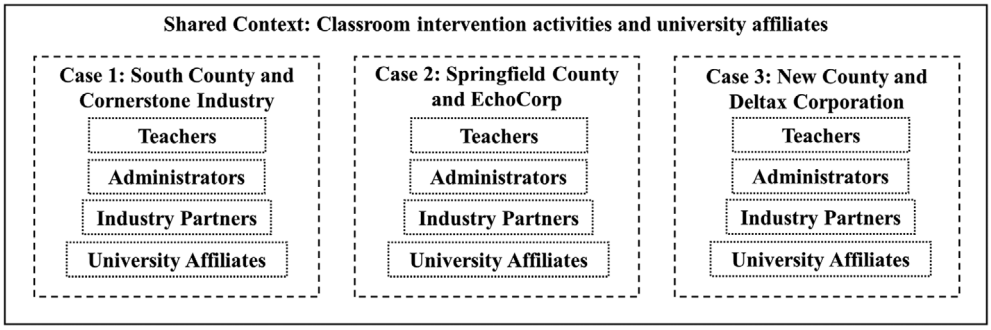

FIGURE 1 Multiple case study design with embedded units of analysis (the stakeholder groups)
Source: Adapted from Yin (2014)

TABLE 2 Participant stakeholder group description and justification for inclusion in our research on interorganizational collaboration

	Description	Justification
Administrators	Initial points of contact for the project that included county administrators (e.g., superintendent or assistant superintendent) and school principals	Their buy-in was necessary for project initiation. Support from administrators is a major factor in making changes to teaching practice (Berebitsky et al., 2014)
Teachers	All 6th grade science teachers involved in the project with varying levels of experience and different educational backgrounds (e.g., formally trained as a social studies teacher, now teaching science)	Teachers' experiences are an underutilized resource when it comes to developing new initiatives (National Academies of Sciences, Engineering, and Medicine, 2017)
Industry	Industry partners in science and engineering jobs holding a variety of job titles and levels of experience. From industries involving chemical and materials engineering, manufacturing, and other engineering subdisciplines	The viewpoint of industry in such a partnership is understudied, especially in research related to teacher professional development. Where studied, challenges involving integrating industry need further investigation (Buxner et al., 2014). 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	Programmatic and research personnel on the project who were interviewed as stakeholders in the collaboration	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 participants

or older who hold a bachelor's degree or higher than the national percentage of 30.3% (U.S. Census, 2016). Also, approximately half of all students in these counties are receiving a free or reduced lunch. 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, a local or well-resourced regional science or engineering focused company was the clear option. This approach also aligns with the promoting and supporting engineering career choices framework for rural youth (Gillen et al., 2018). Although we have argued that the rural contexts are similar, the personal and professional backgrounds of the individual participants varied widely, and this diversity of participants promoted pragmatic validation. Table 3 depicts the number of participants from each stakeholder group in each case. University affiliates were involved in all cases.

3.2 | Data collection

We chose semistructured, open-ended interviews to elicit responses that allowed us to best "understand the world as seen by the respondents" (Patton, 2002, p. 21). Before the first classroom lesson and after the last, these 30–60 minute interviews were conducted with participants. The protocols (see Appendix A) were guided by the five dimensions from the framework of collaboration from Thomson et al. (2007) and supplemented with categories from other research on collaboration such as the communication dimension from Mattessich et al. (2001). Because there were multiple research questions being explored over the whole project, these interview protocols also contain questions related to conceptions of engineering, motivation to teach engineering, reasons for choosing to participate, and engineering self-efficacy. Although these questions were not explicitly designed to help us develop evidence toward the collaboration-focused research, they often added important context to our interpretations for the research question presented in this study. A total of 76 semistructured interview transcripts from 49 participants were generated. Participation in the research was optional, and all programmatic participants were invited to also participate in the research. All of the teachers and nearly all participants in the program were participants in the research. Post-year interviews included new participants such as industry employees who participated in the classroom but were not originally identified and a South County administrator 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. Table 4 shows the specific number of pre-year and post-year interviews collected from each stakeholder group. Pre-year and post-year data were analyzed to substantiate findings through a form of qualitative triangulation of data (Stake, 2006) to support procedural validation (Walther et al., 2013). To establish communicative

	Case 1	Case 2	Case 3	Group total
Teachers	2	4	3	9
Administrators (school and county)	4	5	6	15
Industry partners	5	7	8	20
University affiliates	—	—	—	5
Case total	11	16	17	49

TABLE 3 Number of participants by case

	Pre-year	Post-year	Group total
Teachers	9	9	18
Administrators (school and county)	11	12	23
Industry partners	8	18	26
University affiliates	4	5	9

TABLE 4 Number of interviews conducted by stakeholder group

validation in making the data, informal member checks were performed through the project's programmatic activities in the classroom and in our regular communications.

To ensure process reliability in making the data (Walther et al., 2013), all interviews were recorded using two recorders in case of failure, and the digital recordings were transcribed verbatim and checked for errors made in transcription. Multiple interviewers collected data from participants in this project, and interview guides were developed. Any changes made to the protocol and procedure were discussed as a group. New individuals who joined the interviewing team were given individual instruction in how to collect the data in a similar manner in which it had already been done. Spreadsheets tracking the data managed the manner in which the data were collected across researchers.

3.3 | Data analysis

Because of the volume of interview transcripts and the higher-level results demanded of the research question, the qualitative analysis consisted of holistic coding techniques in which larger sections of data are coded at once as opposed to individual lines (Miles et al., 2013). To promote procedural validation and ensure process reliability, we kept detailed documentation of our analysis and interpretation procedures, which included developing memos and a researcher bias statement (Walther et al., 2013). Figure 2 outlines the steps in our analysis.

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 by Miles et al. (2013). Leaving the option for inductive interpretation, we ensured we were capturing an authentic reflection of the complexity of the social reality and helped support theoretical validation (Walther et al., 2013). Table 5 provides a definition for each of the dimensions from Thomson et al. (2007). It is important to note that these codes were not necessarily 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 (Norms of Trust and Reciprocity), a participant may be simultaneously bounding their own roles (Administration).

We employed cross-case synthesis methods 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 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. Multiple levels of coding also made clear the difference between what was strictly in the data and where our interpretations started to emerge to support process reliability (Walther et al., 2013). Among other strategies, the use of peer debriefing through regular PEERS team meetings promoted communicative validation in handling the data (Walther et al., 2013). Also, in handling the data, pragmatic validation asks if the theoretical interpretations resonate with existing and similar contexts (Walther et al., 2013). In the PEERS program, these research findings have been directly incorporated into the remaining years of practice.

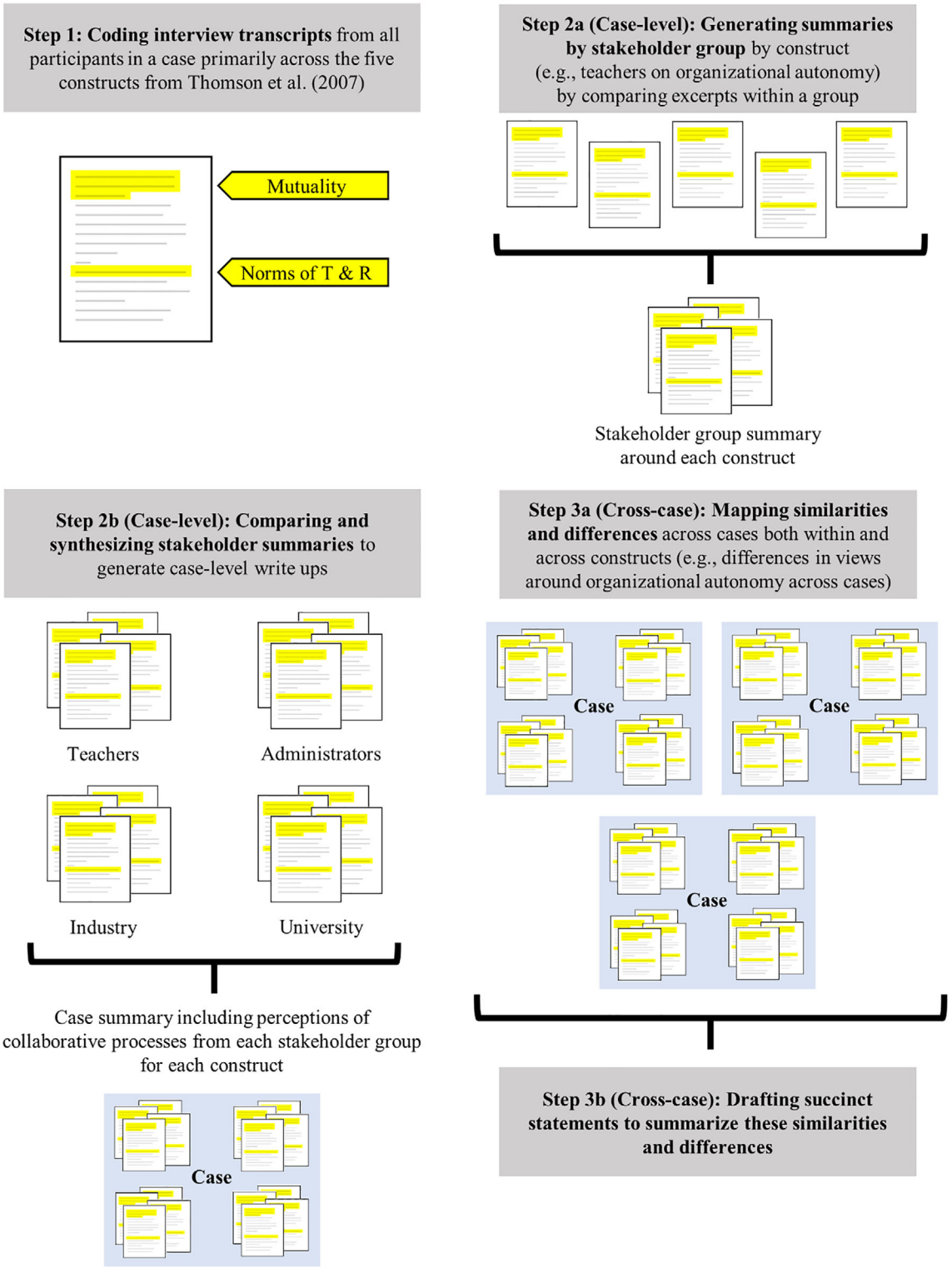

FIGURE 2 How our analysis was built from the case level to the cross-case level. Norms of T & R, Norms of Trust and Reciprocity

3.4 | Research quality

This investigation was guided by the qualitative research quality framework for engineering education by Walther et al. (2013). The framework synthesizes traditional writings on research quality and provides guidelines for qualitative

TABLE 5 Dimensions from Thomson et al. (2007) and definitions

Code	Definition
Governance	Negotiated process of developing working rules and structures around collaborative participation in PEERS
Administration	Implementation and management of governance structures, including clarifying operating mechanisms such as participant roles, communication channels, and monitoring
Mutuality	"Beneficial interdependencies" based on either a complementary exchange of resources within the program or a shared interorganizational mission
Organizational autonomy	The pull between individual organization (i.e., engineering company, school, or university) and collective interest of the PEERS collaboration
Norms of trust and reciprocity	Perceived relative degree of obligation or "I will if you will" and evolving beliefs about partner commitments to the program

Abbreviation: PEERS, Partnering with Educators and Engineers in Rural Schools.

researchers in engineering education and beyond 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. Table 6 is an adaptation of Table 1 from Walther et al. (2013), which 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.

Ethical validation is not included in this summary table and was added as an additional validity construct in a later iteration of the framework (Walther et al., 2015). Particularly because there is a significant power disparity between the teachers working in the schools and the academics and engineers involved in this project, ethical considerations became central. The dynamic between the researcher and the participant becomes particularly important in qualitative research and especially when interviewing (Patton, 2002). 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 were offered to coerce stakeholders to participate in this research. A stipend provided to teachers was separate from the research processes and was meant only as an acknowledgment of their programmatic efforts (e.g., time spent on curriculum development during the summer and feedback on curriculum throughout the year).

4 | FINDINGS FROM THE CROSS-CASE ANALYSIS

Analysis was structured around the dimensions of collaboration from Thomson and Perry (2006) and Thomson et al. (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. Although we engaged in a lengthy process of case-by-case analysis and synthesis across stakeholder groups within a case (Gillen, 2019), we present the findings from the cross-case analysis here to facilitate discussion of broader theoretical contributions and practical implications. Major aspects of the case-by-case analysis are embodied in the cross-case by the nature of the technique. In the following sections, we will go through each dimension in the results with the goal of providing cross-case insights with regards to the dimensions.

4.1 | Governance and administration

Recall that governance is about the working rules and structures of the collaboration, and administration is the implementation and clarification of these governance rules such as the role clarification that nearly all participants experienced. Initial governance and administrative procedures were established by the university; however, this study is itself an exploration of how this was negotiated over time. While some participants were critical of year one governance, others accepted shortcomings as part of a negotiated process. For example, one teacher and the senior manager at EchoCorp in Case 2 as well as a principal and the STEM specialist in Case 3 made comments reflecting this meta-

TABLE 6 Descriptions of data quality constructs and specific study strategies

Typology	Strategies for making the data in this study	Strategies for handling the data in this study	Description
Theoretical validation	Purposeful case selection and construction	Combination of both deductive and inductive analysis techniques	Do the concepts and relationships of the theory appropriately correspond to the social reality under investigation?
Procedural validation	Triangulation Researcher bias statement	Researcher bias statement (interpretive awareness)	Which features of the research design improve the fit between reality and the theory generated?
Communicative validation	Informal member checking Considering contrasting accounts	Peer debriefing Ensuring the connection between theory and literature Using the language of the discourse community	Is the knowledge socially constructed within the relevant communication community?
Pragmatic validation	Diversity of participants	Promoting transferability through detailed descriptions of context Assessing applicability of results through programmatic activities	Do the concepts and knowledge claims withstand exposure to the reality investigated?
Process reliability	Transcript checking Interviewer training Data management	Chronological research journal Levels of analysis explicated through case study design	How can the research process be made as independent as possible from random influences?

Source: Adapted from table 1 "Typology of Quality Strategies" from Walther et al. (2013) (p. 640).

level appreciation of collaboration as a process. 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 (e.g., roles and responsibilities) as the year progresses. Notably, when asked if they had any critical comments about the first year, one teacher in Springfield County 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)

With the notable exception of Case 2, specific individuals channeled key 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, these key individuals were 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. 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. 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 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 added that there was minimal communication among 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. For example, a teacher explained,

> We're gonna have to collaborate with the other teachers in the county. Each school is different in its own way, in its own running, in its 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. ... 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, [the university's] gonna be the one driving it, so you know you're gonna be meeting with them. (South County Teacher)

4.2 | Organizational autonomy

Industry investment in schools had to do with both perceived capacity and company philosophy. The biggest concern for industry participants was balancing making up lost working time with their collaborative efforts. At Cornerstone, the organizational philosophy allowed for flexibility in getting work done. For example, a participant stated, "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." 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 that lessened the tension of collaborating. In contrast, at EchoCorp, unless an individual was particularly invested, collaborating posed a higher barrier. For instance, a manager stated, "If I had to call it a negative it would be the distraction from work ... I'm still funding them and paying for their time."

From the school perspective, despite enthusiasm to join the program, they still emphasized the constraints of the school environment. 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. 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. Generally, these concerns were alleviated by seeing the program in action. 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)

Still, some individuals made similar or even new statements around autonomy at the end of the year. For instance, a principal in Case 3 noted, "I'm not as pleased with the role that I played this year, because I felt like I wasn't as involved ... it's just the time constraints of being the only administrator in a school that is 500 strong."

4.3 | Mutuality

There was evidence of a complementary 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. In all cases, 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, a 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. 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.

4.4 | Norms of trust and reciprocity

The 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 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 (e.g., calling teachers "standoffish" or their actions a "point of concern"). 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. 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 counterevidence of stakeholders feeling better about partners meeting obligations and in some cases exceeding them.

5 | DISCUSSION

Looking across the results from the cross-case in the broader context of the literature, we developed three major discussion points that extend our understanding of the collaborative processes involved in school–university–industry partnership: school collaboration as an emergent and negotiated process, tension in collaborating across organizations, and fair share in collaborating toward a social goal. The major cross-case findings associated with each theme are summarized in Table 7.

5.1 | School collaboration as an emergent and negotiated process

5.1.1 | Reflection in collaborative practice

The theoretical work in interorganizational collaboration (e.g., Gray, 1989) is based partly on negotiated order theory, which emphasizes the interactions among 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 also able to articulate that they were consciously aware of this essential aspect of interorganizational systems, both

TABLE 7 Discussion themes and associated cross-case findings

Discussion theme	Summarized cross-case finding
School collaboration as an emergent and negotiated process	While some participants were critical of year one governance, others accepted shortcomings as part of a negotiated process (governance)
	In most cases, specific individuals channeled key collaborative processes (governance and administration)
	Communication requisite for collaboration, particularly for monitoring and feedback, did not always emerge (governance and administration)
Tension in collaborating across organizations	Industry investment had to do with both perceived capacity and company philosophy (organizational autonomy)
	Evidence from school personal provided unique considerations for the school environment (organizational autonomy)
Fair share in collaborating toward a social goal	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 (mutuality)
	While there was evidence of credibility being built up among partners over time, there was also consensus of misgivings among partners (norms)

corroborating the literature and suggesting the importance of reflection in collaborative practice. The individuals who 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 school change in this way, developing a meta-level awareness of collaboration as a process can help accomplish collaborative goals. 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 in schools (Gray, 1989), this becomes particularly salient.

5.1.2 | 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 among 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. The 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 in schools, but in follow-ups, other individuals were identified as key facilitators of communication or these overseers recanted on their description of role. 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 our study suggest that coordinators must emerge across organizations and this critical role must not just fall to the project instigators such as university researchers.

5.2 | Tension in collaborating across organizations

5.2.1 | Organizational culture

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. Notably, a missing component of the theoretical work on interorganizational collaboration is this impact of differences in organizational culture (Hofstede et al., 2010). In public–private partnerships such as this program, social goals may conflict with economic interests of the company (Stadtler, 2011). The 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 that the same potential autonomy issues manifested differently depending on the work environment as evidenced by the differences between EchoCorp and the other industry partners.

5.2.2 | Balancing costs and 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 et al., 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 us 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.

5.2.3 | The decision to collaborate

For school systems, we argued that 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 our study suggest that even though programmatic goals to improve learning and career prospects for youth align well with school goals, 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 in managing autonomy is often underbudgeted for or ignored completely (Huxham, 1996). Our 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 US education system both historically and currently (U.S. Department of Education, 2017; Fletcher, 2009), 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.

5.2.4 | The ethics of cross-sector partnership

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. 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). Background checks for safety were performed, but 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. 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.

5.2.5 | Teaching beliefs and autonomy perceptions

Teachers are inarguably 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. 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.

5.2.6 | Visualizing organizational autonomy

Incorporating many of the elements discussed so far, Figure 3 illustrates how factors of autonomy add elasticity into the system of organizational and collaborative commitments discussed above. 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.

5.3 | Fair share in collaborating toward a social goal

5.3.1 | The equity principle for cross-sector partnership

The literature on public–private partnership would suggest that the notion of shared benefits is 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). 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. Based on our findings in light of the literature, we propose the equity principle. In partnership, we can conceptualize ensuring equity as a process of evaluating the relative contributions of resources compared with benefits in light of the purpose of the collaboration to determine what balance of costs and benefits is appropriate for each organization. Figure 4 graphically depicts how an uneven exchange of resources can be moderated in this way. The arrows represent the costs and benefits flowing among organizations.

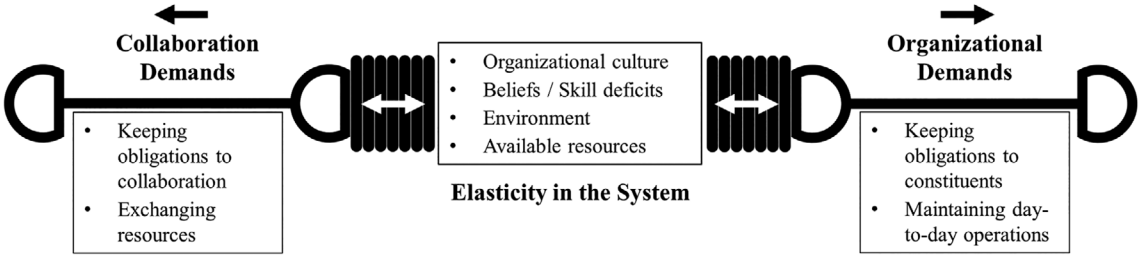

FIGURE 3 Elasticity in organizational autonomy: How factors of autonomy can add elasticity into the system of organizational and collaborative commitments

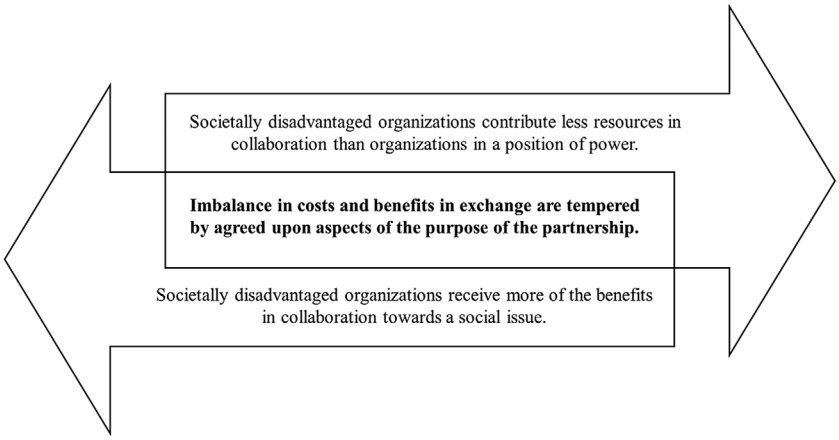

FIGURE 4 Equity in exchange in interorganizational collaboration toward the purpose of addressing a social issue: Moderating an uneven flow of costs and benefits

Moreover, collaborations involving the public sector such as K-12 public education are oriented toward these goals of improving the prospects of the public sector, and therefore, an equal share of benefits would not make sense.

5.3.2 | Managing credibility to support healthy exchange

Stakeholder acceptance of the equity principle is only possible when efforts are being made to address negative perceptions that impact credibility among partners. This may also be directly related to the communication structures and the emergence of key individuals. 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).

6 | IMPLICATIONS FOR RESEARCH AND PRACTICE

6.1 | Implications for research and future work

Through the exploration of a public–private interorganizational collaboration, we 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 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, we have contributed to the development of collaboration theory in the education context. In particular, embedded multiple qualitative case study research allowed for the exploration of the collaborative processes involved when organizations with very different contexts and cultures came together. For example, our findings support the notion of collaboration as an emergent and negotiated process, and we add to this the idea of reflection on the collaborative process for weathering the inherent ups and downs and identifying emergent key individuals who broker partnership. The results of this study also helped us to catalog the insights gained while trying to build a collaborative model of engagement within contexts that typically are situated as an outreach model. Furthermore, through the research process, we 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 a primarily deductive qualitative analysis, we have been able to expand on our understanding of these constructs and the connections among them. For instance, in discussing mutuality, we propose the equity principle in cross-sector collaboration and the need to temper considerations of shared benefits with the purpose of the collaboration. While the theory sparingly connects credibility building to exchange when coming from a position of shared mission, our findings suggest that building this trust through communication practices is key to a healthy exchange of resources in support of the equity principle. Considering organizational autonomy, we also expanded our understanding of tension in interorganizational collaboration between individual and collective goals by establishing that in school–university–industry partnership, amplifying or mitigating factors introduce change into the system as shown in Figure 3.

While coding interview transcripts, it also became apparent that participants frequently used phrasing that implied relational structures explored through this collaboration that, although not always central to this study, provide insights into future work. Most often, individuals situated their organizations as the outsider in the partnership and the other two organizations as collaborators. For example, 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. A meta-analysis of studies exploring collaboration focusing on the specific language used or a quantitizing of the qualitative data from this analysis could yield findings about how the language used relates to actions taken in school–university–industry partnership.

6.2 | Implications for collaborative practice

Sharing both the burden and the benefits is arguably a central piece to collaborative success. To this end, we have developed several questions schools can ask industry and vice versa. For industry, the literature suggests collaborating with an eye toward 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 may promote shared benefits while mitigating unexpected expenditure of resources. Based on our findings, we have developed a reflective tool for practitioners engaging in interorganizational collaboration, which can be found in Appendix B and Grohs et al. (2020).

Managing communication in a dynamic system, such as within the organizations in the PEERS program, and respecting organizational hierarchy while ensuring buy-in and active communication across this hierarchy were challenging. For instance, within the school systems, a grassroots 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. Another 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 "the mutual knowledge problem" (Cramton, 2001, p. 346). 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 teachers 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.

While this research does establish several clear implications for collaborative practice that the literature claims to promote success, complete knowledge of how to develop the PEERS program into a sustainable partnership is not feasible. Moreover, although having sustainable relationships means that efforts toward 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 we have identified factors for success in collaboration, for the PEERS program, what sustainability means is still being negotiated.

6.3 | Implications for projects with both research and programmatic goals

Unsurprisingly, the PEERS program quickly became complex as the university team and collaborators balanced many moving parts within the research and programmatic activities. New classroom lessons had to be created including alignment with science and engineering standards as well as goals of local relevancy. Developing this content, collaborating over a distance, and interfacing with competing demands in the school system undoubtedly contributed to some of the relationship-building difficulties discussed as areas for improvement in the interviews, one example being when EchoCorp participants in Case 2 implied that teachers let the university and industry take on too much responsibility. Design-based implementation projects like PEERS can be structured to improve collaborative practice in direct response to research data (LeMahieu et al., 2017; Russell et al., 2013). For example, by bringing these critical and sometimes uncomfortable conversations to the forefront, we can take steps to improve the collaboration through our summer summit event. This is not a luxury afforded to every partnership, but without the specific structure to strategically react to feedback, the problems discussed here might stay unresolved and ultimately impact long-term success.

7 | LIMITATIONS

This study has several limitations, and here we 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 the analysis. 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 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 set. 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 toward more agreeable responses. Given the national rhetoric around collaboration and STEM education, and the fact that the researcher is seen as a PEERS partner and not a third party, participants may have given answers that they believed were more socially acceptable but not as accurate. As a final consideration, although the university perspective is analyzed across cases, the perspective of the other stakeholders is emphasized. Due to the role of researcher-as-participant, we were hesitant to draw major conclusions from the university affiliate interviews at this stage in the research. There were also fewer interviews with university stakeholders than any other stakeholder group. Future work will consider broader interviews with university affiliates, including those classroom volunteers who were not formal researchers in this study.

8 | SUMMARY AND 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). We conducted this research to better understand how interorganizational relationships focused on secondary STEM development during the initial states of a program. Through this exploration, we built implications for longer-term success and evaluated the viability of collaborative theory through use in a new context. In this way, we advanced the literature around organization theory and 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.

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APPENDIX A

Pre-year semistructured 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).

- Have you been involved in collaborative curriculum development or delivery in the past? Describe.
- What was your perception of the community partner before this project began? The university?
- What influenced your decision to participate in this project?
- In your opinion, what outcomes might result from this collaboration? <prompt for positives and negatives> <prompt for students, school, you personally>
- Who do you think is benefiting from this collaboration?
- What role will/have you played in the collaboration?
- What role will/has the university/industry partner played in the collaboration?
- Have you gotten the information you need to be successful in implementing the curriculum?
- Why do you think the university and your industry partner are part of this program?
- 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?
- 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 do you say? If not, why not?
- Do you know any engineers? Who are they and how do you know them? What type of engineering work do they do?
- What content would you expect in an engineering lesson plan?
- 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>
- 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>
- Do you think it is important to teach engineering to middle school students? Why or why not?
- Are you motivated to teach engineering to middle school students? Why or why not?

Pre-year semistructured interview protocol for industry personnel

- Have you been involved in collaborative work with the school system in the past? Describe.
- What was your perception of this school before this project began? The university?
- What influenced your decision to participate in this project?
- In your opinion, what outcomes might result from this collaboration? <prompt for positives and negatives> <prompt for students, school, you personally>
- Who do you think is benefiting from this collaboration?

- What role will/have you and your company played in the collaboration?
- What role will/has the university/the school and teacher played in the collaboration?
- Have you gotten the information you need to be successful in the project?
- Why do you think the university and the school are part of this program?
- How capable do you feel about teaching engineering to middle school students? What factors contribute?
- Do you think it is important to teach engineering to middle school students?

Pre-year semistructured interview protocol for university affiliates

- Have you been involved in collaborative work with these specific school systems or industry partners in the past? Describe.
- What was your perception of these schools and industry partners before this project began?
- What influenced your decision to participate in this project?
- In your opinion, what outcomes might result from this collaboration? <prompt for positives and negatives> <prompt for students, school, industry, you personally>
- Who do you think is benefiting from this collaboration?
- What role will/have you and the university team played in the collaboration?
- What roles will/have the industry partners/the schools and teachers played in the collaboration?
- Have you gotten the information you need to be successful in the project?
- Why do you think industry partners and the schools are part of this program?

Post-year semistructured 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).

- 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>
- Who do you think is benefiting from this collaboration? Why/How? <prompt for which students are benefiting> <prompt for change since start of partnership>
- What role will/have you played in the collaboration? <prompt for change since start of partnership>
- What role will/has the university/industry partner played in the collaboration? <prompt for was help for 6th grade classes appropriate for student learning needs? Was the amount of university 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?
- Have you gotten the information you need to be successful in implementing the curriculum?
- Why do you think the university and your industry partner are part of this program?
- Any other thoughts about how the collaboration changed over the first year? How has it changed for you specifically?
- What are some, if any, specific challenges that you encountered (or you think the project encountered) during the first year?
- Have your conceptions of engineering or engineers changed since the start of this partnership? If so, how? What factors contributed?
- 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>
- Has your motivation to teach engineering changed since the start of the partnership? Why or why not? What factors (people or things) contributed?
- 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? Have any barriers changed since the start of the partnership (either less or more)?
- What, if anything, do you think makes teaching middle school students in rural communities about engineering different than other communities?

- What, if anything, makes teaching middle school students in your community about engineering different than other communities?
- 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?
- In analyzing the student work, we noticed students from your class [reference specific data], we were wondering if you could provide any insights into why this may be?
- What do you think are the barriers or supports to pursuing engineering as a career for your students?
- Did having PEERS in your classroom change any routine dynamics for the day or surrounding days? How? 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)
- So, you must be thinking ahead to next steps, what would you want next year to look like? <prompt for any steps they have taken toward actualizing their vision>

Post-year semistructured interview protocol for industry personnel

- 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>
- Who do you think is benefiting from this collaboration? <prompt for change since start of partnership>
- 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>
- What role will/has the university/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?
- Have you gotten the information you need to be successful in the project?
- Why do you think the university and the school are part of this program?
- Any other thoughts about how the collaboration changed over the first year? How has it changed for you specifically?
- What are some, if any, specific challenges that you encountered (or you think the project encountered) during the first year?
- Have your beliefs about your capability to teach engineering to middle school students changed since the partnership started? Why or why not? What factors contribute? <prompt for both positive and negative changes to self-efficacy>
- Have your beliefs about the importance of teaching engineering to middle school students changed since the partnership started? Why or why not? What factors (people or things) contribute?
- What do you think are the barriers or supports to pursuing engineering as a career for the students you have worked with?
- So, you must be thinking ahead to next steps, what would you want next year to look like? <prompt for any steps they have taken toward actualizing their vision> <prompt for barriers such as more resources needed>

Post-year semistructured interview protocol for university affiliates

- 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>
- Who do you think is benefiting from this collaboration? Why/How? <prompt for which students are benefiting> <prompt for change since start of partnership>
- What role will/have you and the university team played in the collaboration? <prompt for change since start of partnership>
- 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?
- Have you gotten the information you need to be successful in the project?
- Why do you think industry partners and the schools are part of this program?

- Any other thoughts about how the collaboration changed over the first year? How has it changed for you specifically?
- What are some, if any, specific challenges that you encountered (or you think the project encountered) during the first year?
- What do you think are the barriers or supports to pursuing engineering as a career for your students? <prompt for our students being rural>

APPENDIX B

Evidence-based reflection tool for interorganizational collaboration

Guidelines: This tool can be used both as a 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 continually throughout an ongoing collaboration.

(A) 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?

(B) 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?

(C) A Collaboration is only as good as its people.

It is easy to talk about collaboration and organizations in the abstract, but networks of interacting people 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?

(D) Just because an organization is getting something new does not 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 and that costs to them will be negligible, there can be hidden tensions to participation.

Reflection questions:

- How does collaboration impact my (and my partners') day-to-day work?
- When is adding a new collaboration too much of a good thing?

(E) Collaboration requires identifying what your unique expertise is bringing to a project.

Even in partnerships that appear to be charity-focused 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?

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

Particularly in collaboration toward 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?

(G) 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?