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Benefits, Roles and Tensions: Understanding the Process of Collaboration in Rural Engineering Education Contexts

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Research Statement

Driven by calls from organizations like the National Academy of Engineering [1] over the last decade to increase the STEM workforce, there has been a resulting push to provide K-12 students opportunities to explore fields like engineering. Now, there are many opportunities that exist for students to explore engineering such as robotics programs, LEGO Engineering, and Project Lead the Way [2]. While these programs might be widely available, there may be time commitments students have to make outside of the classroom or fees students might have to pay to participate. In addition to these programs, standards like the Next Generation Science Standards (NGSS) [3] have been developed to integrate "core ideas of engineering design and technology applications" into science classrooms across the United States. However, research has shown that many teachers feel uncomfortable or unprepared to bring engineering into their classrooms [2],[4],[5].

In rural settings, these challenges are amplified. Many rural schools face challenges with access to resources and training due to a lack of funding or geographic distance from areas that have opportunities for training or other resources at institutions of higher education or museums [6]-[8]. Additionally, it is also a challenge to recruit and retain highly qualified teachers in rural areas, and those who are there are often stretched thin while serving many roles in their schools [6]. When it comes to integrating standards like the NGSS, rural teachers have expressed challenges about receiving little to no support, training or materials from districts as new standards are introduced [9]. Because there are often few teachers or only one teacher per grade, rural teachers have communicated feelings of isolation related to having very few opportunities

to collaborate with other teachers [9]. With frequent turnover in school and district administrators, community is hard to establish among rural schools [9].

To counteract some of these challenges many rural communities experience, collaboration between engineers, educators and universities has been argued to be a potential solution to integrating engineering into classrooms [10]-[12]. Collaboration is often a method organizations have used to secure resources and cope with changes [13]. This shared interest stakeholders have in solving problems through collaboration has been defined in literature from Gray [14]. According to Gray [14], some characteristics of problems that can be addressed by collaboration are that they are ill-defined and complex, there are several stakeholders who have varying levels of power, resources and expertise, and existing processes for addressing problems have been insufficient. Gray [14] further argues that there are many benefits of collaborating to try to solve these problems including stakeholders having ownership of the solution, new and improved relationships among stakeholders, and structures for stakeholders to take further action.

Previous studies of collaborations between universities and communities have suggested that communities gained increased access to resources from the university while the university benefitted from an increased presence, and expansion of research and outreach programs [15]. In rural Appalachia, the Appalachian Regional Commission [16] has also suggested collaboration between stakeholders in the region can build economic resilience and support all members of communities.

One such collaboration that exists in Southwest, Appalachian Virginia is called Virginia Tech Partnering with Educators and Engineers in Rural Schools (VT PEERS). The focus of VT PEERS is to provide recurring hands-on activities for students to explore engineering in

classrooms with the support of local engineering industry, university affiliates, and teachers [10]. This study takes place in the context of the VT PEERS partnership at the end of the second of three years of collaboration. This study focuses specifically on the university affiliates and how they understand the process of collaboration. Findings from the analysis of semi-structured interviews suggest that university affiliates understand that there are unequal benefits for participating in the partnership, that roles and responsibilities were unclear for each partner, and that tensions were present between what teachers were asked to do in the partnership and what might have been required of them by their schools.

VT PEERS Context

VT PEERS originally resulted from funding from the National Science Foundation (NSF) Innovative Technology Experiences for Students and Teachers (ITEST) program in 2017 (further described in Grohs et al. [10]). The partnership was initiated by researchers at Virginia Tech, a large, R1, land-grant institution situated in Appalachia and involved middle school teachers and industry partners working in three counties near the institution (two in Appalachia and one bordering Appalachia per the defined map from the Appalachian Regional Commission). The partnership focused on connecting teachers and working engineers in each county to integrate engineering into existing science curriculum as a way to expose students to engineering while still meeting the required state standards of learning. The project initially started working with just 6th grade students and teachers. As the 6th grade cohort moved through middle school, the partnership expanded to include 7th and 8th grade teachers to create more of a structure for continuous student engagement. The final year of the partnership was ultimately interrupted by COVID-19, which created significant challenges related to partner engagement and program sustainability beyond the NSF funding.

The specific geographic region in which this work takes place tends to differ significantly from the rest of the state, and to many, is considered to be rural and geographically isolated. The Blue Ridge Mountains and New River provide much of the landscape for the region. Historically, Southwest Virginia and neighboring West Virginia have been heavily influenced by coal mining and other extractive industries, farming, forestry and manufacturing. This history has had a significant impact on perceptions of Appalachia and current problems Appalachia faces [17]. As of 2017, while these industries do take up a bigger share of the Appalachian Region's employment compared to national employment, the professional and technical services and health and social services industries employ more people in the Appalachian region [18]. Appendix A provides some general demographic information for the three counties involved in the project, as well as an overview of Appalachian Virginia and Non-Appalachian Virginia compared to the Appalachian Region and broader United States [19].

Research Questions

The purpose of this single case study is to explain how university affiliates explain the process of collaboration after the end of the second year of a partnership between a university, local industry partners, and educators in Southwest, Appalachian Virginia. The goals of this partnership are to deliver hands-on engineering activities to rural middle school students through integrating engineering into the existing curriculum and standards of learning. Using a theory of multidimensional collaboration from Thomson and Perry [13], this study seeks to understand more about the structures of collaboration, the role of each partner, the benefits of collaboration, and the overall goals and reflections about the partnership. This study is guided by the following research question:

How do university affiliates understand the process of collaboration after the second year of a collaborative partnership between teachers, universities, and industry?

Theoretical Framework

The theoretical framework informing this study was originally developed by Thomson and Perry [13]. In an attempt to go "inside the black box of collaboration," Thomson and Perry discuss five different dimensions of this process: governance, administration, organizational autonomy, mutuality, and norms of trust and reciprocity (defined in Table 3).

Table 3

Components of collaboration as defined by Thomson and Perry [13]

Component of Collaboration Process	**Definition**
Governance	The understanding of how to jointly govern the behavior of and relationships between partners and creating structures for activities and goals through power arrangements.
Administration	The administrative structure that moves the collaboration forward.
Organizational autonomy	The tension between the self-interest of the partners and the collective interest of the collaboration as it relates to sharing information and responsibility and decision-making.
Mutuality	The mutual benefits between partners that encourage information sharing and ultimately lead to collaboration.
Norms of trust and reciprocity	The common belief among partners that there is respect and an obligation to follow-up on commitments and negotiations.

Thomson and Perry [13] suggest that while all five of these dimensions are important, those involved in the collaboration should seek a balance between all five, which can be achieved through "mutual accommodation.". This can mean renegotiation and be heavily dependent on the context of the collaboration. In fact, previous research using data from the first year of the VT

PEERS project suggests that these five dimensions might need renegotiation [20]. First, Gillen et al. [20] found that there were specific tensions between individual and organizational demands for each group of partners and that to cope with this, there should be elasticity in the system of collaboration offered through autonomy. Additionally, Gillen et al. [20] identified that there is less that disadvantaged organizations are able to contribute to partnerships and more that they receive. Gillen et al. [20] suggest that this principle of equity between partners should be well understood to mitigate negative perceptions between partners.

Continuing to use this lens of a multidimensional model of collaboration on VT PEERS data is appropriate for illuminating the progressing understanding of the process of collaboration among partners. Being aware of how partners renegotiate their understanding of their roles, responsibilities, benefits, and relationships as time goes on allows for deeper insights into best practices and recommendations for future actions and collaborations.

Methodology

This study employed a single holistic case study design as described per Yin [21] to build off the analysis previously completed using data from the first year of VT PEERS. Because the participants of this study belong to the same stakeholder group, the process of collaboration as understood from their perspectives are more likely to be common, making the use of a single holistic case study appropriate [21]. According to Baxter and Jack [22], case study research also allows for the specific context to be understood—in this case, the specific context is the VT PEERS partnership.

Data Collection

Participants

Participants in this study included five university affiliates who participated as a part of the VT PEERS in some capacity. The participants had a range of involvement including faculty members, graduate students and support staff. The university affiliates represent one of four stakeholder groups involved in VT PEERS; the other three groups are industry partners, teachers, and school administrators. These five participants were chosen to represent a range of experiences and insights as university affiliates.

Methods and Protocol

Data were collected from VT PEERS university affiliates using semi-structured interviews after the second year of the partnership during the summer of 2019. Interviews were conducted with participants by a member of the VT PEERS research team. The interviews themselves ranged from 20 to 50 minutes in length. Interviews were recorded and transcribed using a professional transcription service. The interview protocol was developed using the five dimensions of collaboration framework from Thomson and Perry [13] as previously described. The interview protocol was developed to further understand the contexts of continued involvement in the partnership after the first two years. Some questions on the protocol include:

- In your opinion, what outcomes might result from this collaboration?
- Who do you think is benefiting from this collaboration? Why/How?
- What roles will/have the industry partners/the schools and teachers played in the collaboration?

Data Analysis

Data was analyzed using a thematic analysis approach primarily informed by deductive methods and use of theory, though space was left for codes and themes to be developed inductively [23]. A first cycle of holistic coding was completed where large sections of text were coded instead of individual lines [24]. After codes were developed from the data, the codes were organized into themes that were named and further defined. Four themes came from the theory of collaboration from Thomson and Perry and any other themes were developed using inductive methods.

Research Quality

The research quality framework as defined by Walther et al. [25] was used to address issues of reliability and validity at the stages of "making the data and handling the data.". Considerations at the stage of making the data involve making sure the social reality is represented in the data and that the data was collected and recorded in a dependable way. All interviews were recorded, transcribed by a professional service and cleaned of any identifying information prior to analysis. Considerations at the stage of handling the data include ongoing engagement with the data and peer debriefing. Throughout analysis, especially as codes were developed, all transcripts were regularly revisited and codes were added, changed or deleted as appropriate before the development of the final codebook. Additionally, themes were discussed with peers and colleagues to ensure alignment with general expectations within the research community.

Author Positionalities

The following positionality statements are informed by recent research from Secules et al. [26] and recognition that we, as the primary researchers on this paper, understand the context,

methods, and data through a lens of our own experiences and identities. Given the context in which this work was written (i.e. after the end of the formal partnership during COVID-19), only our (the two authors of this paper) positionality statements are provided. We recognize that the perspectives of all of the collaborators are critical to the work of VT PEERS, though we did not formally ask for their involvement in this writing due to the constraints of COVID-19 and varying priorities of collaborators.

Lead Author

I am a white, non-disabled, queer person from southeast, Appalachian Ohio who has been trained in mechanical engineering. My positionality is informed both by the privilege I experience due to being white and non-disabled in a society built on white supremacy, and the marginalization I have experienced due to being queer and Appalachian. As a researcher, I consider myself to be a critical pragmatist and have focused much of my research around asset-based approaches to engineering education and rural K-12 education, questioning how the distribution of resources to rural places can be addressed through locating resources and knowledge in rural communities. The data presented here was collected prior to my involvement on the project. I have gained a lot of context for what has happened over the course of the three year project and have come to understand more about the nuances and complexities of collaboration. I have not personally participated extensively in project activities or had the opportunity to interact with all partners, and my primary experiences on the project have been focused on data analysis.

Second Author

I am a white, male, non-disabled, first-generation college graduate who spent most of my childhood in a small school system and pursued engineering at the state land-grant university. I

was actively encouraged by teachers to pursue engineering. However, looking back I often reflect on how much being a white male student who was performing well in math and science impacted why I was encouraged to pursue engineering. I know there were large groups of students at my school who were not explicitly encouraged to dream about longer term educational pursuits and careers. Looking back at these experiences have made me seek out opportunities to try to improve college access, especially for students who, for whatever reason, are not encouraged to consider how their unique skills and experiences might align well with future engineering and technical careers.

Also relevant here is that I have been a resident of the broader rural region in which this project took place for 15 years and while affiliated with the institution I have also been involved with several organizations doing community-focused work and previously worked for 5 years as a faculty member in institution's office focused on community engagement and service learning. In all of this work, I have come to believe that education and access issues are largely influenced by entrenched systemic issues. Addressing these issues will require sustained investment by many stakeholders, and I believe that the institutions of higher education, especially land grant institutions, and large regional industries engaging together over a sustained period of time with school administrators at the county-level and educators in the schools is a valuable start. Paraphrasing work from organizational theory and collaboration scholar Barbara Gray, collaboration involves forming coalitions of stakeholders and forging diverse interests into collective action. I am deeply committed to this work.

I have been engaged with the broader project reported on here as a principal investigator and so I have influenced much of the programmatic and research design. However, in this paper,

I did not participate in data analysis beyond supporting and discussing findings with the lead author.

Results

From the analysis, a total of six themes were identified. Analysis was ultimately informed by the theory of collaboration as defined by Thomson & Perry [13]. Codes developed from first-cycle holistic coding were integrated into the framework by the creation of themes around the five dimensions: governance and administration (which were combined due to similarity), autonomy, mutuality, and trust and reciprocity. Two additional themes were identified: engineering project goals and looking to the future, which capture codes that do not necessarily fall into the framework. All themes and codes have been included in Appendix B. For the purposes of this paper and to answer the research question, the results section will only focus on those themes informed by the theoretical framework. Though the themes presented below have been separated by dimension, there are many places of overlap and these themes should not be thought of as mutually exclusive.

Mutuality

The theme of mutuality describes how participants discussed the concept of mutual benefits between partners that lead to information sharing and collaboration. The codes in this theme deal broadly with the role of each partner, motivations for joining the collaboration, and the benefits each partner might experience. To start with teachers, one participant discussed some reasons teachers would want to join the partnership as being related to the push for STEM integration in schools and an opportunity for hands-on professional development:

> *I mean there is a big push to teach STEM kinds of things, and the literature shows that, that teachers can struggle with doing that. And why wouldn't they? Because they weren't*

trained to do it. But now all of a sudden it's an important thing. And few teachers are former engineers. So why would they have the skillset? And really, in some ways for teachers, rather than going to a conference, it's kind of like a hands on professional development that comes to them...(University Affiliate 5)

However, in discussions with some teachers, another participant identified that administrators may not have been as supportive of teacher involvement in this project:

They may feel like they're being held so much to the SOL (standards of learning) *outcomes that this might be seen as a diversion from their actual performance metrics that they're going to be held to. And so I'm not sure that they feel like they've been given the space by the administrators to do the work. (University Affiliate 7)*

Another participant identified that the primary role of teachers was to help develop lessons aligned with the standards of learning:

So the role of teachers has been, I think it has been sort of working with us to develop the lessons and to make sure that we are covering material that they need to cover anyway, based on the standards that they are supposed to teach. So helping us develop the curriculum, and then also helping us to deliver the curriculum and offering us the time in their classrooms, opening their doors, letting us in... (University Affiliate 8)

Another participant indicated that through this partnership and working with university affiliates and engineers to integrate engineering, one benefit for teachers is ultimately becoming more comfortable with engineering. Though industry members are likely benefitting on an individual level, many participants suggested that industry joined and is primarily benefiting from having a presence in the community, which may be complicated by not fully understanding their role in classrooms. For example:

It seemed like they all had the same habit of, after seeing the first class, they warmed up and knew what to do in the second and third class. It seemed like they didn't entirely know what they were walking into when they came into the classroom. (University Affiliate 5)

Overall, many participants seemed to agree that students benefited from this partnership through meeting or interacting with people who work as engineers in their communities. Across all five interviews, participants suggested that the role of each partner varied or that each partner's roles were unclear. Additionally, each participant suggested that while everyone benefits from this collaboration, the benefits are not quite the same.

Trust and Reciprocity

The theme of trust and reciprocity deals primarily with the respect and trust built between partners which creates an obligation for partners to follow-up on their commitments and responsibilities. For teachers, one participant suggested that the relationships built in the partnership have allowed teachers to stay committed to their jobs while having new language and ideas to advocate for their students:

I mean, that's the teachers, but I think it speaks to the relationship we built with the teachers that they're continuing to do the job, they probably have always done, of advocating for their kids. And I think they just have maybe new language and new ideas for that. (University Affiliate 3)

As teachers have had to make shifts in the classroom to accommodate this engineering integration, one university affiliate partner played a major role in making sure teachers were comfortable with the decisions and shifts made throughout the first two years of the partnership:

I think that {University Affiliate 4} really tried to support that change or that shift in roles for teachers by sort of asking them what they felt comfortable engaging with. But I think that {University Affiliate 4}'s a very ... She has the principles of kind of community development and knowing that it has to sort of stem from within them. (University Affiliate 6)

Another partner identified how important it was to have genuine relationships developed within the context of the partnership and how having everyone on the same page helps with decision making and trust among partners:

And I think that it speaks to {University Affiliate 4} but it also just speaks to that we've developed genuine relationships with some of the teachers over time. And how it's amazing to me how important that is. (University Affiliate 3)

In the context of this partnership, establishing trust among partners was key. Participants suggested the importance of another university affiliate in establishing this trust, and making sure that decisions were made through consulting with partners.

Governance and Administration

The dimensions of governance and administration were combined from the original framework because of the similarities and overlap in how participants discussed both concepts. Recall that governance relates to the understanding of how to govern activities and create structures within the partnership and administration refers to the structures that move the collaboration forward. Communication within the partnership was discussed by many participants. In some instances it seemed as though a lack of communication made it difficult for partners to understand their roles. For example:

> *...there's often been a perception from the teachers that they don't fully understand what's going on or what's expected of them, and so I feel like there were some missed opportunities there in communication in terms of either communicating, or better explaining what the expectations were for their participation in the project. (University Affiliate 7)*

Another participant attributed this to teachers, for example, being "voluntold" to participate in the project, and how that creates problems with communication of expectations and roles:

> *I think, of course, that the teachers, when they can't opt in themselves, when you're voluntold in a sense, I think that there's less engagement, less involvement. And I think that that may have been a little bit of a breakdown in communication too, in terms of what is my role in this project. (University Affiliate 6)*

In addition to communication, there were some structural challenges related to the initiation of the partnership that did not allow for important, relationship-building interactions between partners:

> *...in the first year it felt like something we were doing to people, not with people. We did all the curriculum development in the first year and delivered all of the curriculum in the first year. And the teachers I think were less active partners. We didn't get funding in time to do the summer summit before the first year as we originally planned. And I think that would have helped start to build the partnerships a little bit better, because I mean I know a whole group, a whole bunch of people worked really hard to go out to individual schools to recruit people to participate. (University Affiliate 5)*

Another participant suggested that, for reasons presented above, some partners seemed less engaged and perhaps did not understand the expectations and goals set for them:

They seem less engaged than in a perfect world, and I think that is because their lives are very full of lots of other things, or maybe in some cases they didn't choose it. I'm not really sure. (University Affiliate 8)

Though two years since the start of the project, participants noted how impactful the start of the project was for expectations, goals, and even clarity of partner roles in the collaboration. Having the time and ability to establish activities, roles, and responsibilities at the start of the project would have allowed for a more shared understanding and structure of the partnership.

Organizational Autonomy

Organizational autonomy deals with the tensions between individual partners' interests and the collective interest of the partnership, particularly as it relates to responsibilities and decision making. In the context of this partnership, participants expressed concerns about how decisions were made in the context of school systems and tensions teachers probably experienced due to priorities of the school systems and the priorities of the partnership. For example, one participant briefly discussed the complexity of school systems with administrators that make decisions that directly affect teachers:

I think we have several, lots of people with expertise in community engagement or community organizing on our team and yet, I feel like we learned a lot about that process because school systems are such interesting animals with multilayered administration and decision making that directly impacts teachers. (University Affiliate 3)

Another participant went on to explain the tensions a teacher might feel if they were told to do something they did not think was best for their classroom:

I think that teachers are often told, "You're doing this thing that that we're telling you you have to do," and they didn't choose it. And it may get in the way of what they think is

right for their classroom. It may be something that they aren't not naturally drawn to, and they wouldn't have chosen it. (University Affiliate 8)

One university affiliate expressed that some of the decisions made in the context of the partnership may have been at the expense of some of the goals of the project but that being responsive to schools and teachers was more important:

I will say that whenever you do this kind of work where there are a lot of different stakeholders involved, you have to be flexible and you have to be responsive, and I feel like we've been flexible and responsive…but we've tried to accommodate a lot of different requests and needs that are specific to teachers or specific to the schools, or specific to school systems. We've done that in a way that I think is very authentic, it's really valuing the idea that we really didn't intend to push something on a school system, we really did want to hear what their needs were. (University Affiliate 7)

Many participants expressed the need for teachers to continue to take ownership of the classroom activities and engineering lessons as it pertained to the sustainability of the program beyond the funding timeline.

Making decisions and participating in a partnership can be incredibly difficult given priorities each partner might have outside the context of this collaboration. Participants expressed a need for more ownership and autonomy to be given to teachers in particular if the collaboration between educators and industry is expected to continue beyond the funded grant.

Discussion

The purpose of this study was to understand how university affiliates involved in VT PEERS explain the process of collaboration after the end of the second year of the partnership. The analysis of semi-structured interviews with the university affiliates point to three main

takeaways informed by the multidimensional theory of collaboration defined by Thomson and Perry (2006): unequal benefits between partners, clarity of roles and responsibilities, and tensions between partnership and priorities.

Unequal Benefits Between Partners

Though all participants seemed to agree that all partners benefitted in some way from their involvement in VT PEERS, the level to which different partners benefitted was unequal. Though not explicitly named a stakeholder, many participants seemed to agree that students were primary beneficiaries of this partnership. Additionally, teachers and schools, who may already struggle with having time and resources to incorporate new things in their classrooms [9], were also named as one of the primary beneficiaries. Though university affiliates benefit from name recognition and expanding their research portfolios [15], it seemed unclear exactly how industry partners benefitted. Some participants mentioned benefits like community engagement and investment in the region, though arguments around pulling students into the pipeline to pursue careers in these industries were not as salient for university affiliates.

This specific finding is well aligned with findings from Gillen et al. [20]. In the first year interviews, it was clear that stakeholders felt there were unequal benefits to all groups and perhaps even felt some tensions with that idea. However, in this partnership, it is clear that different stakeholder groups possess differing levels of power. For example, university affiliates are more associated with the grant money and research directions. School administrators can make decisions that ultimately affect teachers. Industry partners can choose how involved they want to be. With these varying levels of power and resources, it makes sense that benefits would not be equally shared among all partners which requires a balance of mutuality and reinforcing aspects of trust and reciprocity among partners [13], [14]. Gillen et al. [20] argued that this

balance is therefore equitable, in which there are more resources available and able to be exchanged from those partners who have more power to those partners who have less power and therefore benefit more. It is important that this theme carried beyond the first year of the partnership and it seemed as though university affiliates were able to understand more about what each partner is able to contribute or receive from this collaboration.

Clarity of Roles and Responsibilities

Each partner in VT PEERS had differing roles and responsibilities however, university affiliates were not convinced these roles and responsibilities were made clear enough. Some teachers were unsure to what extent they should be leading lessons in their classrooms versus letting VT PEERS team members lead which may have been further complicated by being "voluntold" by administrators to participate in the partnership. Some industry partners were more hesitant to join in classroom activities, finding it easier to sit to the side or help with clean up. Even the role of administrators was perhaps unclear, leading to confusion about how involved they can or should be in classrooms, and miscommunication about expectations or the value of participation. A few participants specifically identified how the rollout of the project during the first year might have affected this. Due to delays beyond the control of the project team, opportunities to build relationships, establish trust, and enact collaboration structures were missed at the beginning of the partnership.

This clarifying of roles and responsibilities extends across many of the dimensions of Thomson and Perry's theory of collaboration and affects all dimensions differently. Clarifying roles might help partners understand how benefits are distributed unequally but equitably, and even help clarify how partners should interact with each other and within the partnership. It is important that opportunities for partners to interact early in the partnership are created.

Tensions Between Partnership and Individual Priorities

Though university affiliates did not necessarily express tensions between their own roles in the partnership and at their institution, they did identify these tensions as being present primarily in schools. The common sentiment of being "voluntold" to participate may have made some teachers uncomfortable especially if they were already uncomfortable with teaching engineering [4], [5]. This may have also created feelings in which teachers felt like perhaps this was not the best situation for their classroom or their students, but because in many cases administrators have more power, teachers have an obligation to follow [9]. However, there were some cases in which university affiliates identified teachers who were excited to participate but administrators felt as though there was little value in participating in the partnership, citing tensions between partnership priorities and school priorities like student success related to testing and state standards of learning.

The VT PEERS team tried to balance these feelings of tension by being responsive to the needs of teachers and schools, and as one participant pointed out, sometimes at the detriment of the partnership itself. These tensions were identified in the first year data by Gillen et al. [20]. Understanding these tensions individuals experience is important for understanding how to balance dimensions like organizational autonomy in partnerships. Partnerships and collaboration require time and energy commitments that may stretch partners beyond what they may normally experience [13]. Being responsive and flexible at times can help ensure success, establish trust and help build relationships, however it is crucial that partners understand the importance of the role they play in the partnership.

Implications

These three takeaways previously discussed point to some challenges of collaboration that would be transferable across many educational contexts. While collaboration does offer many benefits in educational settings, it is clear that there can still be tension between stakeholder groups, particularly as it pertains to understanding who is benefitting, how they are benefitting, and what each group's role is or should be. Lessons learned from VT PEERS point to the need to establish relationships, trust, and communication early on in partnerships to facilitate interactions and mitigate tensions. Additionally, it is crucial to recognize the competing priorities that different stakeholder groups might have. In education in particular, these competing priorities might be due to standardized testing and other school metrics that tend to be much of the focus. For engineering education, there may be an added layer of teachers not having engineering experience and being unsure of how to engage with engineering in their classrooms.

Limitations

This study only focuses on one group of stakeholders in a multi-stakeholder partnership. Therefore, all perspectives presented in this paper are from the lens of university affiliates and their perceptions about school administrators, teachers, and industry partners. Additionally, using the single case study approach only illuminates the context of the partnership as understood through the single case. Another limitation is that the theoretical framework only highlights certain aspects of collaboration and the protocol only included questions specifically around these dimensions of collaboration. The framework was also used to inform data analysis, so the lens through which this data collection and data was viewed was very limited in nature.

Conclusions

Collaboration can be an incredibly complex process involving many stakeholders with different perspectives and approaches to engaging. However, collaboration can also be incredibly beneficial particularly as it relates to the distribution of time, energy and resources among stakeholders. In the context of education in rural places, where teachers and schools may be stretched too thin, collaboration is crucial. As K-12 continues to adapt to calls for expanding the engineering workforce and adopt standards that integrate engineering into science curriculum, collaboration may be one viable way to ensure the success of students and teachers.

Future research should continue to analyze data from different stakeholders across all contexts of collaboration to understand how they have processed the experience. Additionally, future research could benefit from utilizing other frameworks, particularly those frameworks around sensemaking [e.g. 27] (e.g. Weick et al., 2005) that would allow for participants to reflect and make sense of the process of collaborating. Frameworks around boundary spanning [e.g. 28] would also be useful for understanding more about the tensions partners experience between individual and organizational priorities.

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References

[1] National Academy of Engineering, "Expanding underrepresented minority participation: America's science and technology talent at the crossroads," 2011. [Online]. Available: https://www.nap.edu/catalog/12984/expanding-underrepresented-minority-participation-americas-science-and-technology-talent-at

[2] S. Brophy, S. Klein, M. Portsmore, and C. Rogers, "Advancing engineering education in P-12 classrooms," *Journal of Engineering Education*, vol. 97, no. 3, pp. 369–387, 2008, doi: 10.1002/j.2168-9830.2008.tb00985.x.

[3] National Research Council, *Next Generation Science Standards: For States, By States*. Washington, D. C.: The National Academies Press, 2013. doi: 10.17226/18290.

[4] R. Hammack and T. Ivey, "Examining elementary teachers' ngineering self-efficacy and engineering teacher efficacy," *School Science and Mathematics*, vol. 117, no. 1–2, pp. 52–62, Feb. 2017, doi: 10.1111/ssm.12205.

[5] J. Utley, T. Ivey, R. Hammack, and K. High, "Enhancing engineering education in the elementary school," *School Science and Mathematics*, vol. 119, no. 4, pp. 203–212, 2019, doi: 10.1111/ssm.12332.

[6] S. Ardoin, *College aspirations and access in working-class rural communities: the mixed signals, challenges, and new language first-generation students encounter*. Lanham: Lexington Books, 2018.

[7] P. W. Garner, M. Carter McLean, B. Waajid, and E. R. Pittman, "Mentoring and professional development in rural head start classrooms," *Mentoring & Tutoring: Partnership in Learning*, vol. 23, no. 4, pp. 293–310, Aug. 2015, doi: 10.1080/13611267.2015.1099868.

[8] S. L. Hartman and S. Kahn, "Benefits of community-university partnerships in rural settings: Lessons learned from an inclusive science day event," *CJCRP*, vol. 2, no. 1, p. 6, Jan.

2019, doi: 10.33596/coll.20.

[9] D. Zinger, J. Haymore Sandholtz, and C. Ringstaff, "Teaching science in rural elementary schools: Affordances and constraints in the age of NGSS," *The Rural Educator*, vol. 41, no. 2, pp. 14–30, Sep. 2020, doi: 10.35608/ruraled.v41i2.558.

[10] J. R. Grohs *et al.*, "Building community capacity for integrating engineering in rural middle school science classrooms," *Journal of STEM Outreach*, vol. 3, no. 1, p. 12, 2020.

[11] P. Knutson and D. Del Carlo, "Impact of multiplex relationships on rural science education," *The Rural Educator*, vol. 39, no. 2, pp. 21–35, Nov. 2018, doi: 10.35608/ruraled.v39i2.203.

[12] J. K. Roberts and P. D. Grant, "What we know and where to go: A systematic review of the rural student college and career readiness literature and future directions for the field," *The Rural Educator*, vol. 42, no. 2, pp. 72–94, 2021, doi: https://doi.org/10.35608/ruraled.v42i2.1244.

[13] A. M. Thomson and J. L. Perry, "Collaboration processes: Inside the black box," *Public Administration Review*, vol. 66, no. 1, p. 12, Dec. 2006, doi: 10.1111/j.1540-6210.2006.00663.x.

[14] B. Gray, "Collaboration: The constructive management of differences," in *Collaborating: Finding common ground for multiparty problems*, Jossey-Bass Inc., 1989.

[15] V. O. Paton, "The scope of our country: Expanding access to higher education through community partnerships with Texas Tech University," *Journal of Higher Education Outreach and Engagement*, vol. 11, no. 1, pp. 25–39, 2006.

[16] Appalachian Regional Commission, "Strengthening economic resilience in Appalachia: A Guidebook for practitioners," 2019. [Online]. Available:

https://www.arc.gov/research/researchreportdetails.asp?REPORT_ID=150

[17] E. K. Peine, A. P. Azano, and K. A. Schafft, "Beyond cultural and structural explanations of regional underdevelopment: Identity and dispossession in Appalachia," *Journal of Appalachian Studies*, vol. 26, no. 1, pp. 40–56, 2020, doi: 10.5406/jappastud.26.1.0040.

[18] Appalachian Regional Commission, "Industrial make-up of the Appalachian Region: Employment and earnings, 2002-2017," 2019. [Online]. Available: https://www.arc.gov/research/researchreportdetails.asp?REPORT_ID=161

[19] National Center for Education Statistics, "ACS-ED district demographic dashboard 2014-2019," 2019. [Online]. Available: https://nces.ed.gov/programs/edge/acsdashboard

[20] A. L. Gillen, J. R. Grohs, H. M. Matusovich, and G. R. Kirk, "A multiple case study of an interorganizational collaboration: Exploring the first year of an industry partnership focused on middle school engineering education," *Journal of Engineering Education*, vol. 110, no. 3, pp. 545–571, 2021, doi: 10.1002/jee.20403.

[21] R. K. Yin, *Case study research: Design and methods*, 5th ed. SAGE, 2014.

[22] P. Baxter and S. Jack, "Qualitative case study methodology: Study design and implementation for novice researchers," *The Qualitative Report Volume*, vol. 13, no. 4, pp. 544–559, 2008, doi: 10.2174/1874434600802010058.

[23] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, 2006.

[24] M. B. Miles, A. M. Huberman, and J. Saldaña, *Qualitative data analysis: a methods sourcebook*, Third edition. Thousand Oaks, Californinia: SAGE Publications, Inc, 2014.

[25] J. Walther, N. W. Sochacka, and N. N. Kellam, "Quality in interpretive engineering education research: Reflections on an example study," *Journal of Engineering Education*,

vol. 102, no. 4, pp. 626–659, 2013, doi: 10.1002/jee.20029.

[26] S. Secules *et al.*, "Positionality practices and dimensions of impact on equity research: A collaborative inquiry and call to the community," *J Eng Educ*, p. jee.20377, Feb. 2021, doi: 10.1002/jee.20377.

[27] K. E. Weick, K. M. Sutcliffe, and D. Obstfeld, "Organizing and the process of sensemaking," *Organization Science*, vol. 16, no. 4, pp. 409–421, 2005, doi: https://doi.org/10.1287/orsc.1050.0133.

[28] D. J. Weerts and L. R. Sandmann, "Community engagement and boundary-spanning roles at research universities," *The Journal of Higher Education*, vol. 81, no. 6, pp. 632–657, Nov. 2010, doi: 10.1080/00221546.2010.11779075.

Appendix A - Demographic Context

Table 1

Contextual demographic information for the three counties involved in VT PEERS, Asterisk (*) denotes ARC-defined Appalachian county

	County A*	**County B***	**County C**
Total Population	30,767	16,772	78,376
Public School Information			
Locale Classifier	Rural: Fringe	Town: Distant	Rural: Fringe
Student/Teacher Ratio	~ 13:1	~ 12:1	~ 14:1
Community Demographics - Race/Ethnicity (%)			
White	94	95	88
Black	2	2	7
Hispanic or Latino	2	2	2
Asian	1	0	1
American Indian/Alaskan Native	0	0	0
Hawaiian and Other Pacific Islander	0	0	0
Some other race alone	0	0	0
Two or more races	1	1	2
Families with income below the poverty level (%)	21.6	5.3	10.7
Parental Educational Attainment (%)			
Less than a High School Graduate	7.6	5	5.3
High School Graduate	37.9	32.4	24
Some College or Associate's Degree	37.3	43.5	31.4
Bachelor's Degree or Higher	12.1	18.8	39.3

Table 2

Contextual demographic information for Appalachian and United States contexts

	Appalachian Virginia	**Non-Appalachian Virginia**	**Appalachian Region**	**United States**
Total Population	741,895	7,793,624	25,717,174	328,239,523
Demographics (%)				
White alone (not Hispanic)	88.8	58.6	80.7	60.1
Black alone (not Hispanic)	5.5	20.4	9.9	12.5
Hispanic or Latino	2.6	10.5	5.4	18.5
Other (not Hispanic)	3	10.5	3.9	8.9
Persons in Poverty (%)				
All ages	18.6	9.8	15.2	13.4
Under 18	23.9	13.1	21.2	18.5
Educational Attainment (%)				
Less than High School Diploma	15.9	9.7	12.8	12
High School Graduate	54	42.1	53.6	47.4
Associate's Degree	9.3	7.6	8.9	8.5
Bachelor's Degree or More	20.9	40.6	24.7	32.1

Appendix B - Codebook

Themes	Codes	Sub-codes
Engineering project goals	Engineering focus	Messaging about engineering
		Supports for pursuing engineering
		Barriers to pursuing engineering
Looking to the future	Sustainability of partnership	-
	Lessons learned from partnership	-
Mutuality	Roles of partners	Role of educators
		Role of university affiliates
		Role of industry
		Shifting roles
		Comfort with role
	Motivations for joining partnership	Educator motivations
		Industry motivations
	Benefits for partners	Educator benefits
		Industry benefits
		University benefits
		Student benefits
		Unequal benefits
	School administration influence	Challenges
		Support
Trust and Reciprocity	Relationships between partners	Relationships and responsibilities
		Relationships and decisions

		Importance of relationships
	Trust between partners	-
Governance and administration	Communication within the partnership	-
	Structures of partnership	-
	Goals of partnership	-
Organizational autonomy	Decision making	General decision making in partnership
		Decisions and tension in partnership
	Ownership of facets of partnership	-