Board 284: Exploring and Supporting Non-STEM Teachers' Engineering Identity Development during Implementation of an Engineering Design Elective Course in Rural Middle Schools

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Abstract

This paper will discuss the engineering identity development of two rural middle school teachers who are implementing an engineering design elective course while working in staff positions not specific to science, technology, engineering or mathematics (STEM) instruction within their schools. As an Innovative Technology Experiences for Students and Teachers (ITEST) project, this research-practice partnership (RPP) in advanced manufacturing engineering is designed to provide community-based engineering design experiences for underserved middle school students (grades 6-8) from rural NC. While one of the goals of this project is to improve non-cognitive outcomes (i.e., interest, self-efficacy, and STEM identity) and increase participation in engineering for students, a significant byproduct is the development of engineering identity of the middle school teachers.

Rural schools face distinctive challenges in teacher recruitment and retention, particularly in STEM subjects. This project takes a unique approach to filling the gap in the limited number of STEM-qualified teachers in rural areas by providing professional development support for non-STEM teachers who are teaching the 3-part grade level specific engineering design elective course at their middle schools. Using a narrative inquiry approach, this paper will describe how an individualized professional development structure has impacted two non-STEM teachers as they teach the elective engineering course. Despite their limited STEM backgrounds, the teachers have developed a strong sense of engineering identity alignment through strategic, just-in-time professional development supported by K-12 outreach specialists, STEM content rooted in existing community industry assets and real-world experiences, and consistent administrative support for continued pedagogical and content knowledge development. Operationalizing teacher identity frameworks, this study has implications for engineering and teacher educators as well as community-engaged STEM outreach professionals in considering the importance of identity development opportunities for teachers within research-practice partnerships.

Introduction

United States (U.S.) support for improving STEM education has been strong in the last two decades, driven by the idea that the nation's success in K-12 STEM education directly correlates to the number of workers entering the STEM workforce, which greatly impacts the nation's economic health [1], [2], [3]. In December 2022, the U.S. Department of Education announced the "Raise the Bar: STEM Excellence for All Students" initiative, intended to "help implement and scale equitable, high-quality STEM education for all students from Pre-K to higher education—regardless of background— to ensure their 21st century career readiness and global competitiveness" [4]. One of three *Raise the Bar* goals is to "develop and support our [U.S.] STEM educators to join, grow, and stay in the STEM field" [4]. This goal targets one of the most significant challenges facing the education field today: teacher recruitment and retention.

The COVID-19 pandemic has magnified the teacher shortage in the U.S. Recent research by the National Center for Education Statistics reports that "nearly half (44 percent) of public schools currently report full- or part-time teaching vacancies" in 2022, somewhat due to additional strain on teachers as a result of the pandemic [5]. However, what *Raise the Bar* and other similar initiatives fail to address is place-based inequity for student access to STEM instruction. Teacher vacancies, which historically occur in greater numbers in rural areas, often result in rural teachers being responsible for teaching content outside of their certification area [6], [7]. Despite this challenge, rural schools are still greatly underrepresented in education research literature [8], [9]. Thus, rural student access to STEM instruction, the STEM identity development of rural students and teachers, and the way place and space influences either issue, remain underresearched and underpublished issues. The lack of scholarship in these areas is problematic, because around one in five Americans – or nearly 20% of the population, and more than 9 million school-age children – live in rural areas [10], [11].

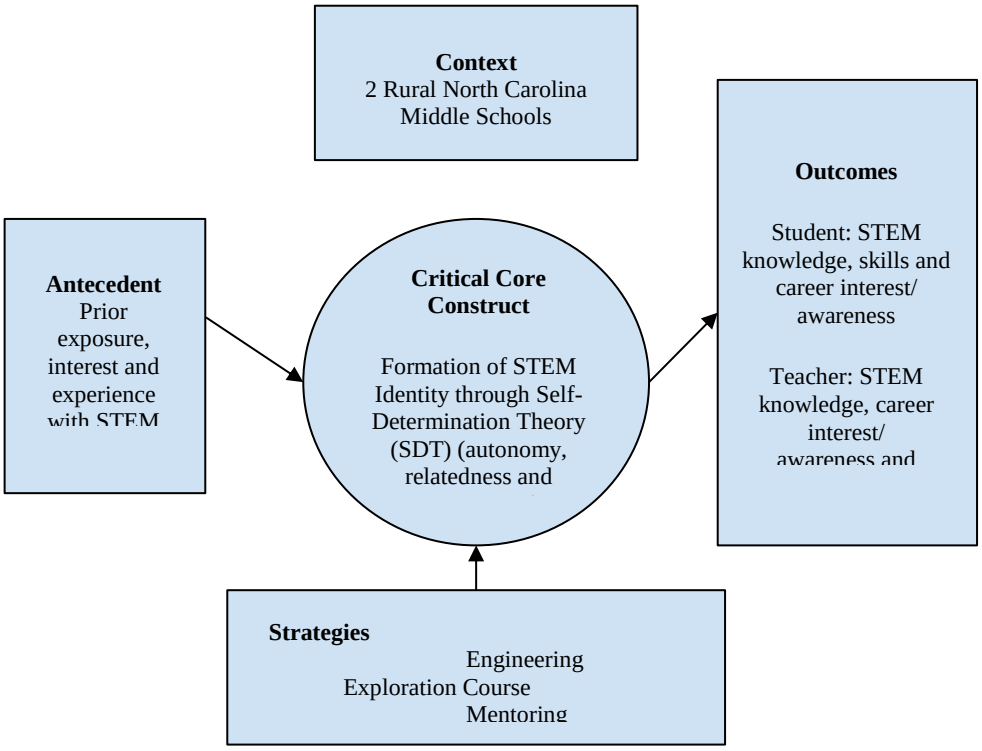
While rurality creates several unique challenges to teacher recruitment and retention, such as fewer financial incentives to join and stay in the teacher workforce, lack of resources for classroom and instructional support, and challenges with technology access, one of the most significant challenges is lack of access to high-quality professional development [6], [12], [13], [14]. Teacher professional development opportunities can be critical for teacher pedagogical growth, and can strengthen teacher ability to tailor instruction to student academic needs [15]. Further, Bowen et al. [6] illustrate that "teachers who have engaged in targeted professional development have reported they significantly increased the use of workforce development skills in the classroom as a pedagogical tool to engage students in authentic 21st century learning" (p. 58). The notion of using "workforce development skills" as a "pedagogical tool" has heightened implications in rural settings. Rural America is largely perceived as economically failing, and rural students are "less likely to enroll in or complete college, are inclined to have lower academic self-concepts and are subject to rural stereotype threat often exacerbated by poverty" [16]. By negotiating school learning as a tool to advance toward workforce readiness, rural teachers can support students in overcoming rural stereotypes and, if there is local industry relevant to their field of instruction, can mitigate rural brain drain.

Theoretical Background

"Identity" is more than just who we think ourselves to be. Identity in and of itself is a complex and fluid construct with several different definitions and applications across many spectrums including race, gender, situations, and professional disciplines. Benson et al. [17], using Harré's [18] three conceptions of self, conceptualized six main facets of identity: (1) embodied identity, or the self as perception within a body, (2) reflexive identity, or the self's view of self, (3) projected identity, or the self as projected to others by oneself through interaction, (4) recognized identity, or the self as perceived by others through interaction, (5) imagined identity, or the self's view of future opportunities and possibilities, and (6) identity categories and resources, or the self as characterized using social categories (p. 19). The concept of teacher identity, in terms of these facets of identity, emphasizes the multi-faceted way that teachers develop their professional identities over time and through interactions with self and with others. Identity is not static nor do people "achieve" one certain level of identity, but rather it is constantly changing and evolving in response to social interactions, experiences, goals, and beliefs.

Barkhuizen et al. [19] applies these facets of identity to a broader understanding of the development of teacher identity that incorporates autonomy and agency. In this context, teachers having *agency* indicates that teachers have the ability to, and do, take action to direct and control their work and in general, their life [20], [21]. Likewise, *autonomy* as a construct asserts that individuals are inherently drawn to grow, master challenges, and integrate new experiences as they continually develop and refine their own sense of self [22]. According to Benson [20], "autonomy and identity are linked through the idea that any sustained process of learning is also a process of *becoming*" (p. 18). Notably, autonomy is one of the key concepts of self-determination theory (SDT) [22]. This ITEST project titled, *Developing STEM Identity in Rural Audiences through Community-Based Engineering Design (DeSIRE)*, is guided by and grounded in self-determination theory as demonstrated in our Theory of Action. Our Theory of Action, illustrated in Figure 1, is based on the expectation that students and teachers entered the DeSIRE ITEST program with varying degrees of prior STEM exposure, interest, and experience. Researchers within our research-practice partnership expected that these differences would impact how the student and teacher participants would approach and engage in the program components and strategies, leading to differentiation in the outcomes for each participant.

Figure 1. *DeSIRE Project Theory of Action*



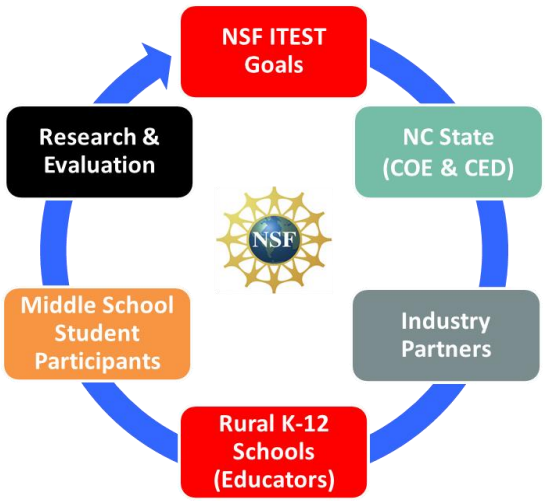
The importance of teacher autonomy and agency in developing teacher identity is amplified when teachers are building pedagogical and content knowledge in an academic area in which

they have not been formally trained, as is the case in this study. Patrick & Borrego [23] presented a comprehensive review of literature on engineering identity, concluding that there is little research that "actually addresses engineering identity development" (p. 19). Despite the national emphasis to increase the number of engineers entering the workforce in the U.S., there is a continued insufficiency at disentangling engineering from the greater integration of "STEM." What does it mean to have an *engineering identity* rather than a STEM identity? Due to the lack of an established definition of engineering identity across the literature, we make use of the following definition of STEM identity in analyzing the data collected for this study: STEM identity describes the extent to which an individual perceives themselves as a STEM person within their understanding of STEM concepts and careers [24], [25], [26].

Program Description

This study is part of a four-year project aimed to connect rural middle school students (grades 6-8) to STEM career opportunities in the advanced manufacturing industry in their local community through a 3-part grade-level specific engineering design elective course. The course engages students in real-world engineering design experiences and STEM activities intended to increase their interest in STEM careers, particularly engineering. These students, the majority of whom are from underrepresented populations, begin the DeSIRE program as sixth graders and continue through to the eighth grade. This project represents a collaboration between the College of Engineering (COE) and the Friday Institute for Educational Innovation within the College of Education (CED) at North Carolina State University (NCSU), the North Carolina Mathematics and Science Education Network Pre-College Program (MSEN), a rural school district in NC, and local advanced manufacturing companies. Figure 2 below illustrates the STEM knowledge transfer model guiding the program.

Figure 2. *Program STEM Knowledge Transfer Model*



Industry Partnerships

The project team partnered with STEM professionals from five world-renowned companies with advanced manufacturing facilities in the surrounding area of the two collaborating schools. Those companies represent three industry segments: food, pharmaceutical and energy systems industries. The STEM professionals largely serve in managerial positions within their respective companies. They have had a number of important roles on the project including, collaborating on curriculum development for the engineering design course and as invited guest speakers in the classroom. However, industry engagement has been limited recently due to employee retention and supply chain issues that continue to plague the manufacturing sector in the wake of COVID.

Mentoring & Supplemental STEM Enrichment Activities

The middle school students were mentored by undergraduate students in the Women & Minority Engineering Program at NCSU. Mentors attended select class sessions to support the teachers and to help guide students through various in-class STEM activities. In addition to mentoring, students have the opportunity to participate in supplemental STEM enrichment activities through the MSEN Saturday Academy and Summer Scholars programs. These supplemental activities allow students to gain additional STEM content knowledge and career awareness in an informal setting.

Teacher Professional Development (PD)

Neither of the two teachers working on this project had a STEM background and are currently in non-STEM related positions within their schools. As a result, the project team implemented a just-in-time PD approach whereby teachers were provided with timely STEM content on an ad hoc basis depending on their work schedules and availability of the PD facilitators [27]. The two PD facilitators are K-12 STEM outreach specialists and have a wealth of experience in this area. As part of the PD, facilitators employed an open door policy that encouraged teachers to reach out for additional support as needed even outside of scheduled sessions. A typical PD session during the academic year lasted for one hour and included time for STEM content knowledge acquisition and lesson planning. Teachers were expected to develop lesson plans tailored to their strength areas and were able use the PD sessions to garner additional feedback from the facilitators. There was also a one week long PD workshop held over the summer where teachers spent full eight hour days delving deeper into STEM content and technologies. Each teacher participated in a total of 40 hours of PD over the course of this study.

Purpose and Research Question

The purpose of this study is to explore the impact of individualized professional development on the engineering identity development for non-STEM teachers. These interviews were conducted using an interview protocol grounded in a narrative inquiry approach to answer our overarching research question [28]. We sought to understand: How and to what degree does strategic, just-in-time professional development within a research-practice partnership influence teacher engineering identity?

Methods

Context

This project is an RPP between the COE and the Friday Institute for Educational Innovation at NCSU, the MSEN Pre-College Program, two middle schools in a rural school district in North Carolina, and advanced manufacturing industry partners local to the rural school district. Both of the middle schools in this project are majority-minority schools and most of the students served by these schools are non-white. The North Carolina county in which both middle schools are situated has a population of approximately 48,000 people, with a median household income of just over $45,000 [11]. In this county, nearly 37% of children live in poverty, and 66% of students would be first-generation college students if they intend to enroll [29]. In terms of engineering education alignment, only 14% of 3rd through 8th graders in the county earn "college-and-career-ready scores" in mathematics [29].

Recruiting and retaining teachers has historically been, and continues to be, a struggle for the school district within this RPP. Between 2006 and 2018, one of every five teachers left the district each year on average. The 20% teacher turnover rate contributes to the county's dearth of available teachers to deliver instruction in STEM courses, a consistent problem in rural areas across the country. Our work highlights the opportunity of research-practice partnerships in delivering professional development to teachers in order to minimize this gap.

Participants

The participants of this study were two teachers at the two middle schools in the partner rural school district. Neither teacher identified as STEM or engineering teachers, instead both teachers were in "digital literacy coach" roles in their district. The participants interviewed are the primary middle school contacts within the research-practice partnership; in general, the university research staff and the STEM professionals directly communicate with these teachers when discussing the project. For the purposes of this paper, to protect the anonymity of our participants, we will refer to the teachers as "Gary" and "Sean." Because the teachers frequently discuss their experiences with the STEM outreach specialists, we have also given them pseudonyms, and will refer to them as "Ronald" and "Andrew."

Procedures

To investigate the experiences of teachers within the work of this project, we conducted 60-minute, semi-structured interviews. While quantitative data on teacher identity and self-efficacy development has been collected throughout this project, for this study, we chose to conduct and analyze qualitative interviews using narrative inquiry. Polkinghorne [30] states that narrative study is "a subset of qualitative research designs in which stories are used to describe human action" based on cognitive experiences (p. 11). As discussed earlier, teachers take action, or have agency, regarding their experiences, goals and beliefs. Using narrative inquiry provides an opportunity for participants to describe their choices and reasoning for identity achievements. Narrative inquiry also requires researcher attention to three "commonplaces" as defined by Connelly & Clandinin [31]: temporality, sociality, and place. We posit that these teachers have

not only been influenced by their participation in this project, rather their lived teaching experiences of past and present (temporality), their interactions with others, such as our STEM outreach specialists (sociality), and the rurality of place where their schools are situated.

The two teachers in our project were interviewed separately via Zoom. The virtual interview format was strategically selected in order to be thoughtful of teacher time at the beginning of the school year, to avoid using in-person professional development time as research time, and in observance of the approximately one-hour distance between the research university and the teachers' work sites. Teacher interviews were conducted immediately after an annual, week-long, in-person professional development session for teachers, which was led by STEM outreach specialists within the research-practice partnership. In-depth interview questions encouraged the teachers to tell the story of how they were individually impacted by time-invested, individualized professional development.

Data Analysis

After the interviews were transcribed, they were uploaded to ATLAS.ti, a qualitative data analysis software program. Polkinghorne [30] offered two ways to analyze narrative inquiry methods: (1) narrative analysis, or (2) analysis of narratives. In the first, researchers "reconstruct" stories, or narratives, told by the participants in a fictionalized way "in which different interviewees' voices can be mingled into one voice to protect the identities of the individuals" [32], [33]. The second concept, analysis of narratives, is the analysis approach employed in this paper. Analysis of narratives operates like many other forms of qualitative analysis, where "narratives are analyzed into themes and categories" (p. 636) [34]. Interview data was coded using a combination of inductive and deductive codes. A combination coding approach was selected because the interview conducted for this paper was the second round of interviews with each teacher. As such, the research team anticipated some repeated themes from the first round of interviews, but still started with open or inductive coding to allow the data themes to emerge naturally, followed by a round of deductive coding.

Results and Discussion

There were three significant themes that emerged from the teacher interviews: (1) Teacher pedagogical self-efficacy, (2) teacher motivation to learn content, and (3) relationship management.

Teacher Pedagogical Self-Efficacy

The "teacher pedagogical self-efficacy" theme emerged as the most salient component of engineering course implementation for the non-STEM teachers. The way Gary and Sean perceived their own ability to teach the engineering content, with or without the professional development provided within the research-practice paradigm, influenced their beliefs on how well their engineering instruction was planned, implemented, and received by students. Gary and Sean both emphasized the importance of their ability to "shift," or to move instructional plans around as needed. This is notable within this RPP, because a key component of the professional development programming are instructional deliverables, including complete presentations with

ready-to-present content and activities. Gary expressed how the pre-packaged content helped him frame his instruction:

> The PowerPoint that the STEM professionals gifted me was so important, because it just went step by step through the process and said, this is what you need to focus on. Here are the five steps of engineering. Here's a section on spreadsheets. So they would have to have knowledge of the manufacturing process and some hands-on. We have the Arduino kit, we have Tinkercad and we have the Lego kit…so that students can see how manufacturing works and see the end result.

In the above quote, Gary mentions several engineering-related software and hardware items that he did not understand or know of prior to his engagement in this project. If they so desired, Gary and Sean could have taken the pre-packaged instructional materials and delivered the engineering content word-for-word from the provided framework. However, both teachers underlined the importance of – and their ability to – tailor their instruction to their students' academic and personal needs. Sean told a story about how he looked ahead in the provided content framework and, after understanding the content, decided to create his own activity that better suited his students:

> I'll get a really good idea, and then I'll be like, 'Oh, I'm going to go to the store and buy this real quick, and then we'll do it the next day.' And I think that just little things like poster board, markers, I bought baking soda and gel capsules. So, they manufactured their own pill, per se, and they saw how tedious that has to be based on weight and things. So, although I was provided the scales, I went out and bought the baking soda and the capsules, because it was an idea I had that I wanted to do within the next day.

We further observed that the teachers' pedagogical self-efficacy was directly influenced by their past professional teaching experiences. At the time of their participation in this project, the teachers were working in their school district as "digital literacy coaches," but both had extensive teaching and administrative experience. Gary, for example, was a career and technical education (CTE) teacher for more than 20 years, and Sean was a history teacher and then a principal before returning to the classroom. As the teachers engaged in more PD for this project, they expressed a feeling of increased competence in combining their past experiences with concepts that were new to them. Gary shared how he has fused his previous teaching experience with his new role within the RPP:

> All the time I just taught CTE. I was never really interested in coding. I knew that I was interested in technology and manufacturing and students doing, having, and obtaining goals and being successful in their [job] search. But this has allowed me just to connect manufacturing and technology together.

Teacher Motivation to Learn Content

The ad hoc approach to supporting the teachers took a significant amount of time for both teachers and the STEM outreach specialists, but was instrumental in the teachers' ability to integrate their growing STEM content knowledge into their own STEM identity. Gary reflected

upon the way the just-in-time professional development offered by the STEM outreach specialists complemented the summer PD:

> Last year, of course, I met with the whole team and they welcomed me on board and gave me an overview. And then, we met for 10 hours virtually, in the fall. And I received a PowerPoint to help guide me through the process for the students. So I was working through that and continually wanted to know what help I needed, where, what direction I was going, where I was, how could they help me take the next step? Andrew brought down a lot of supplies one day and came in and met me…and I think there were quarterly check-ins with the whole team. And so, I did check-ins with the whole team. And in the spring, we had an additional 10 hours of video conferencing, more PDs online, more suggestions.

Moreover, both teachers recognized the importance of engaging with the engineering content on their own, outside of the initial professional development training and meetings planned for the project. Gary and Sean conveyed a sense of responsibility to learn the content as a way to incorporate real-world applications into their classrooms. Because the RPP includes industry partnerships, the teachers were motivated to connect the project content with student ability to obtain engineering-related careers. Gary in particular felt a duty to "broaden knowledge" for students to know about career opportunities:

> What I have always explained to students that this was about manufacturing. And some of the jobs and abilities, the opportunities that they would have in manufacturing. So get down through the list [of industry partners], they're all completely different. And so someone would think, "Well, I don't want to stand there and make cupcakes all day or put frosting on cupcakes all day, but I don't want to get dirty and work on an engine all day." I'm just broadening their knowledge of how everything works and on all the different opportunities. I understand, not everyone's going to be an engineer. We use the engineering process to promote the manufacturing design and opportunities, but there is so much more.

Relationship Management

The just-in-time professional development structure within this project served the teachers' STEM identity development in ways other than pedagogical and content knowledge. Over time, the teachers described building relationships of trust and mentorship with the STEM outreach specialists as well as other administrative staff and researchers within the RPP. Sean talked about how one of the STEM outreach specialists engaged with his learning and understanding about the engineering concepts:

> Ronald is just, he knows how to make you feel good. He's that personality. So, he makes me feel as if when that light bulb goes off, he acknowledges when that light bulb goes off. And so, reinforcing to me, it's like, "Oh, okay. I do get it then. I'm not just winging it. I have a foundation where I have some understanding that I can go ahead and take and move forward." So, I think just being that positive affirmation piece, it's just reassuring that yes, it's being done right, or yes, I have the capacity to do it right.

The notion of trust was particularly underlined. Both teachers expressed that it was important to them that the non-teachers within the RPP understood the challenging parts of teaching, like lack of access to resources, time constraints and even pandemic-related challenges like internet access in rural communities. Moreover, the teachers stated that without researcher-practitioner trust building, the university staff could end up seeming more like "big brother," overseeing their actions and looking for mistakes rather than growth. One way that the STEM outreach specialists attended to building trust was to understand the sociality of the teachers, that is to understand their "feelings, hopes, desires, aesthetic reactions, and moral dispositions" and how it relates to their work [32]. For Gary, that meant appreciating that his wife, also a retired teacher, was a large part of his teaching support system, a common phenomenon in rural spaces. In his interview, Gary talked about how the STEM outreach specialists integrated what was important to him into the project:

> Matter of fact, she [Gary's wife] is going to come out and bring lunch out in a little while. She helps me get organized. She helps me with things with the students. And she actually went to the STEM Camp five out of the ten days. And so, they just welcomed her in, gave her own name badge, included her and everything. It's just one of the best fit groups that I've ever worked with, because everyone is concerned about everyone else and wants everyone else to succeed and is willing to do whatever it takes to help another person succeed, it's just great.

Here, Gary is talking about a summer program that students within the RPP are encouraged to attend, which takes place on the university campus. Both teachers opted to serve as the trip chaperones as a way to mitigate parent anxiety, because they were a trusted mediator between the school and the university. By considering Gary's motivations (in including his retired teacher wife, who is also his primary support system), the university staff and STEM outreach specialists built rapport which made Gary feel more comfortable, and increased his feelings that the "group" – the persons involved in the RPP – "is one of the best fit groups that I've ever worked with."

It is crucial to note that the trust within the STEM outreach specialist-to-teacher relationships were not built in one in-person professional development session. As emphasized, the STEM outreach specialists in this project took a "just-in-time" approach, which means that the teachers could, and did, reach out to the specialists whenever they ran into a content knowledge challenge. Sean describes how important it is to him to be able to communicate on an as-needed basis:

> I really value the time that Andrew and Ronald spend with me, helping just work out issues on project-based learning. Andrew is just a rockstar. If there's an issue, then he can look at it and immediately see how you can make it better. Ronald, I really value Ronald because he's persistent and he's going to persevere and get you the information and show you what needs to be done to be successful. So the two of them, just...video meetings with one or the other, those really help me out a lot.

Summary

This paper described the development of teacher engineering identity as a result of a just-in-time (JIT) professional development from STEM outreach specialists within a research-practice partnership (RPP). The teachers described an ecosystem of learning where they were given pre-packaged material, but their motivation to engage deeper with the content on their own, with support from the STEM outreach specialists, exercised their autonomy and competence in the engineering content knowledge base. By understanding that the teacher identity is not limited to in-classroom experiences but also extends to the teachers' moral positioning, feelings, hopes and desires, more meaningful, trustworthy and reliable relationships were established between the teachers and other stakeholders within the RPP, which led to deeper teacher investment in becoming "engineering" people.

Despite challenges during this project, such as teacher turnover and the COVID-19 pandemic which forced several professional development sessions to a virtual format, the "open-door," JIT approach to teacher PD had positive effects. This format increased teacher engineering identity alignment by providing an encouraging, collaborative partnership where teachers felt comfortable asking questions and making mistakes, which led to growth in engineering content knowledge and interest. Future work should include the development of a framework for non-STEM teacher professional development planning and implementation strategies that could support future RPPs between universities and rural school districts.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 1949454. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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